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SURVEY OF THE CHEMICAL COMPOSITION OF COTTON FIBERS, COTTONSEED, PEANUTS, AND SWEETPOTATOES. A LITERATURE REVIEW.

By

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INTRODUCTION

The need for adequate and accurate information of the composition of commodities intended for industrial use or for food is fairly obvious; but to be useful, such information should be readily available and not spread through the literature or hidden away in card files. One purpose of the present literature review is to present such information in a useful form. Another even more important purpose is to show where our knowledge of the composition of the commodities under investigation is inadequate or lacking, so that efforts may be directed toward the investigation of new substances and new groups of substances. Due to the profound influence of the composition of a commodity on its use, any new information on the kind and amount of substances present will be of great value to a program directed toward finding new uses. In this connection a word about "minor" constituents is in order. This term is in many ways unfortunate, since such constituents are usually minor in amount only, and not in importance. They frequently have a profound influence on the usefulness of a commodity and on its processing. Examples will be given later in this review. An understanding of the composition of a commodity is also essential to its correct chemical analysis, since in the selection of methods of analysis or in the development of new methods one must know what interfering substances may be present.

Since a knowledge of what is not known about the commodities is necessary as a guide for efficient research, the substances commonly found in plant material are listed in a simplified form in Table 1 where the thoroughness with which they have been investigated in cotton fiber, cottonseed kernel, peanut kernel, and sweetpotato root is indicated. In this chart an "A" indicates several rather thorough and conclusive papers on the subject, "B" indicates at least one paper dealing with the component in the particular commodity and an asterisk indicates that one or more substances were actually isolated. The really interesting places on the chart are the vacant places or perhaps those where there is only one or more papers indicated by a "B". These represent the places where new information can readily be obtained, and show the more fruitful places to expend effort. The chart also brings out the fact that cotton fiber, cottonseed, peanuts, and sweetpotatoes, by virtue of their vegetable origin, are quite similar in composition from a qualitative standpoint. The same types of substances are found or may be expected to be found in at least small amounts in all of these commodities. For this reason, the methods and procedures for the study of the composition of all of the commodities are similar, and there is considerable economy of effort in working on all of the commodities at the same time.

In the following sections, the chemical constituents of cotton fiber, cottonseed, peanuts, and sweetpotatoes are dealt with in some detail. An attempt has been made to include all substances reported to be present in the commodities, except where later literature has rather definitely shown the substance to be absent or incorrectly identified. Cases where the evidence is weak are usually indicated. The mention of a substance does not necessarily mean that its presence has been proved. Where there are numerous references on the same substance in a particular commodity, the ones chosen are intended to be representative and to contain citations to other literature.

Table 1. Present State of Knowledge and Lack of Knowledge of the Composition of Cotton Fiber, Cottonseed, Peanuts, and Sweetpotatoes

Constituents	Cotton fiber	Cottonseed kernel	Peanut kernel	Sweetpotato root
Cellulose	A*	B	B	B
Starch	B	B	B	A*
Pectin	A*	B	B	B
Pentosans and Pentoses	B	B	B*	B
Sucrose		B	B*	B
Hexoses (dextrose, fructose, etc.)	B		B*	B
Other sugars, such as raffinose		A*		
Glucosides, saponins, etc.		B		
Protein and total nitrogen	A	A	A	A
Protein composition		A	A	A
Other nitrogen compounds	B*	B*	B*	B
Lipids, fats, and oils		A*	A*	
Phosphatides and organic P comps.		B*	B	B
Organic sulfur compounds				
Waxes and higher alcohols	B*	B		
Sterols (phytosterol, sitosterol, etc.)	B*	B*	B	B*
Pigments (carotenoids, flavones, etc.)	B	B		B*
Gossypol		A*		
Organic acids (citric, malic, etc.)		B	B	B
Ash and its constituents	A	A	A	A
Enzymes		B	B	B
Vitamins		B	A	A

A Thoroughly investigated.
B One or more papers at least mention constituent in commodity.
* Isolation of more or less pure substances accomplished.

CHEMICAL COMPOSITION OF COTTON FIBERS

A knowledge of the origin and development of the cotton fiber is an aid in understanding its composition. Shortly after the cotton flower opens, the epidermal cells on the young seeds begin to grow and elongate, forming long, tube-like cells with an ultimate length 1000 to 4000 times cross-sectional diameter. In about 20 days the cell wall starts to thicken and at about the thirtieth day elongation practically stops.

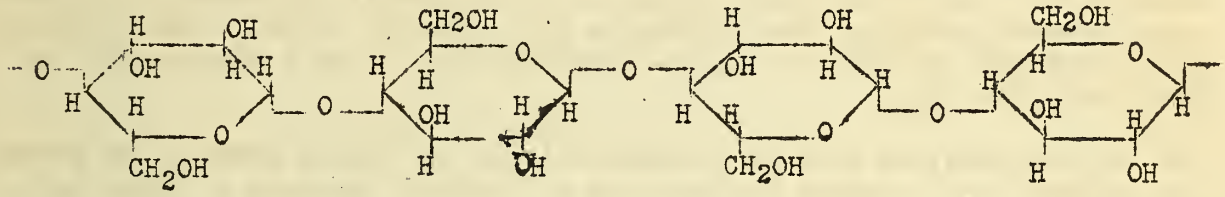
At about the fortieth day the fiber begins to dry and collapse. When the boll opens on about the fifty-fifth day the fiber is a dry, ribbon-like cell with a thick wall of cellulose. The composition of the fiber reflects its cellular nature. Although cellulose is the major constituent, any of the substances commonly found in plant cells may be expected to be present in at least small amounts. The typical mature cotton fiber has a composition illustrated by the selected values given in Table 2.

Table 2. Composition of Typical, Mature Cotton Fiber

Constituent	Percent of dry weight[a]		
	Typical	Low	High
Cellulose	94.0	88.0	96.0
Protein (N x 6.25)	1.3	1.1	1.9
Pectic substances	1.2	0.7	1.2
Ash	1.2	0.7	1.6
Wax	0.6	0.4	1.0
Total Sugars	0.3		
Pigment	Trace		
Other	1.4		

a Moisture about 8 percent regain.

Cellulose: The chief component of the cotton fiber is cellulose, which may be defined as a linear polymer consisting of glucose anhydride units linked through the 1 and 4 carbon atoms by β glucosidal linkage. The number of glucose anhydride units per molecule varies over wide limits, but the average number per molecule for cellulose from cotton is about 2000. The structural unit of cellulose of the cotton fiber is illustrated by the following formula:



The cellulose content of raw cotton fiber ranges from 88 to 96 percent of the dry weight (13, 57, 62)*, a content higher than in any other large commercial source. Scoured, bleached, dry cotton fabric is approximately 99 percent cellulose. The variation in values for the cellulose content of raw cotton fiber is due to natural variations brought about by conditions of soil, climate, and variety of cotton, and especially to conditions which arrest fiber development such as drought, disease, and early frost. Low cellulose content usually indicates a high proportion of thin walled, immature fibers which contain a high proportion of non-cellulosic substances.

Small differences in the values reported for the cellulose content may be due to uncertainty in the analytical methods employed for the determination of cellulose. These methods are usually based on the extraction of all other substances from the cotton with sodium hydroxide (37), monoethanol amine (51) or chlorine followed by sulfurous acid (15) and determining the residual cellulose by weighing or by wet oxidation with sulfuric acid-dichromate mixture. These methods may lead to low values by dissolving small quantities of cellulose or to high values due to incomplete removal of non-cellulosic material. A steady loss of cellulose, amounting to

* Literature citations on pages 13 - 18.

0.3 percent per hour when cotton is boiled with one percent sodium hydroxide has been reported (67).

Moisture: Moisture in cotton and in cotton fabrics is usually expressed in terms of percent regain. This is determined by measuring the loss of weight of a sample on drying to constant weight, dividing this value by the dry weight of the sample and multiplying by 100. The temperatures commonly used range from 105 to 110° C., but higher temperatures up to 120° C. have been employed when speed was desired and the dried sample was not to be used for subsequent tests. If it is important that the properties of the cotton be not altered, the sample may be dried in a vacuum oven at 60° C.

The average percentage regain of American cotton in the bale on arrival in England was 8.51 with a range of 7.05 to 11.47 percent (49). The average regain value for bale cotton in North Carolina has been given as 8.25 percent. An accepted standard for natural cotton yarn is 7.0 percent regain which represents approximately the amount of moisture present in cotton at 65 percent relative humidity and 21° C. Although the non-cellulose components of cotton are said to be more hygroscopic than the cellulose, the ability of cotton to take up or give up moisture is affected to only a small extent by kier boiling or bleaching (61).

Raw cotton and cotton fabrics exhibit hysteresis in the absorption and desorption of moisture. If two samples of the same cotton, one completely dry and the other saturated with water, are placed in an atmosphere of the same relative humidity, the dry sample will attain a regain value considerably below that of the wet sample. Exact studies of this phenomenon have been made (25, 61).

The correct moisture content is essential for the proper spinning of cotton and moisture has a marked influence on the tensile strength of yarns and fabrics.

Wax: The material extracted from cotton fiber with chloroform, carbon tetrachloride, benzene, or other organic solvents is usually referred to as wax. From the standpoint of processing, wax is the most important group of constituents of the fiber other than cellulose. The typical, mature cotton fiber contains about 0.6 percent wax and most of the values reported in the literature range between 0.4 and 0.8 percent (41). Cotton wax may be classed with the plant cuticle waxes and is similar in x-ray diffraction pattern (27) and other properties to the well known carnauba wax.

Presumably most of the wax is located in the cuticle of the fiber, but the difficulty with which it is removed suggests that at least part is located within the fiber or is bound to the cellulose. This is well brought out by the observation (39) that additional wax may be extracted from benzene-extracted cotton, if it is tendered with hydrochloric acid and ground to a powder prior to another extraction. This procedure increased the benzene extractable material from 0.63 to 1.22 percent. When the same original cotton was ground to a fine powder without acid tendering, 1.20 percent benzene extractable material was obtained. Other investigators found that cotton yielding 0.47 percent chloroform extractives prior to treatment gave

0.63 percent after tendering with hydrochloric acid (19). A recently proposed method for estimation of wax in cotton fiber is to extract with 95 percent alcohol in a Soxhlet extractor, mix with and transfer to chloroform by dilution with water in a separatory funnel, wash the chloroform with water to remove nonwax substances, evaporate the chloroform, and weigh the residue (12).

The wax has a profound influence on the wetting properties of the fiber. Raw cotton will float for days on a water surface, while cotton dewaxed by heating with dilute sodium hydroxide or by extraction with organic solvents will sink in a few minutes. The presence of wax is necessary for proper spinning since it lubricates the fibers. Dewaxed cotton does not behave satisfactorily in the spinning process (38). Due to its lubricating properties, the natural wax of cotton decreases the tendency of the fibers to cling to each other (56), reduces the friction between fibers, and hence lowers the tensile strength of yarn and fabrics. Increases of as much as 25 percent in tensile strength have been reported when yarn or cord made of raw cotton was extracted with benzene or other wax solvents (35).

The composition of cotton wax has been investigated by a number of workers (6, 17, 20, 21). It is likely that many of the higher alcohols, acids, and other compounds isolated from cotton wax were really mixtures. Chibnall and others (4) concluded that montanyl alcohol and gossypyl alcohol are mixtures of C_{28}, C_{30}, and C_{32} alcohols, and that cotton wax contains all the even-numbered-carbon primary alcohols ($C_nH_{2n+1}OH$) and normal fatty acids ($C_nH_{2n}O_2$) from C_{24} to C_{34}. The alcohol present in the largest amount is probably n-triacontanol ($C_{30}H_{61}OH$) and the acid present in the largest amount is probably n-tetracosanoic acid ($C_{24}H_{48}O_2$). Small amounts of fatty acids, probably palmitic ($C_{16}H_{32}O_2$), stearic ($C_{18}H_{36}O_2$), and oleic ($C_{18}H_{34}O_2$) are found in the wax. Such compounds could come from seeds broken in the ginning process. The wax also contains small amounts of sitosterol and its glucoside, sitosterolin. Other constituents reported to be present in the cotton wax are: glycerol, resinous material, amyrin ($C_{30}H_{50}O$), ceryl alcohol, and hydrocarbons, including a solid, probably heptacosane.

Cotton wax can be fractionated on the basis of solubility in petroleum ether into cotton wax A (more soluble fraction, about 70 percent) and cotton wax B (less soluble fraction, about 30 percent). Clifford and Probert (6) give the following values for the wax from Mississippi Delta cotton: wax on the dry cotton, 0.49 percent; melting point, 76.5° C.; density, 0.976; acid value, 29; saponification value, 57; saponification value after acetylation, 137; acetyl value, 84; iodine value, 27; unsaponifiable matter, 68 percent; and acetyl value of unsaponifiable material, 123. They call attention to the presence of a large proportion of free wax alcohols and the low amount of wax esters in cotton wax.

A genetic strain of cotton having a green-colored lint has been found to contain 14 to 17 percent wax (11). This wax has a melting point of 85 to 95° C., considerably higher than that of wax from ordinary cotton fiber.

The fibers of this strain of cotton are thin-walled and the possibility of combining the high wax content character with the desirable characters of ordinary cotton, in order to make cotton a commercial source of both fiber and wax, appears to be remote from the genetic standpoint (14).

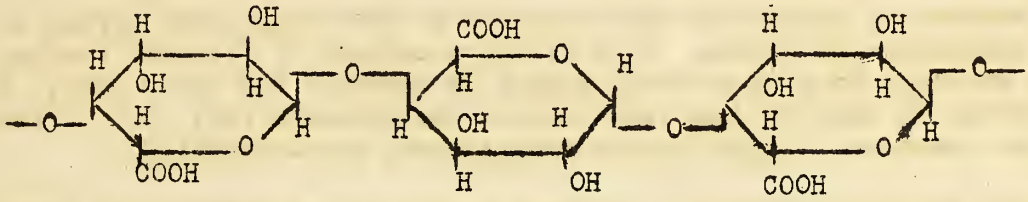
Fate of Wax in the Scouring Process: The usual alkaline kier boil to which raw cotton fabric is subjected prior to bleaching and dyeing does not remove all the wax. Boiling raw cotton containing 0.76 percent wax with 1 percent sodium hydroxide for 5 hours at atmospheric pressure reduced the wax content to 0.31 percent. When such cotton was boiled at 2.5 times atmospheric pressure for 2 hours with 1 percent sodium hydroxide, its wax-content was reduced to 0.26 percent (40). According to Farghor and Higginbotham (18) experimentally scoured cotton has a wax content of about 0.2 percent, while technically scoured cotton has a wax content of about 0.3 percent. Apparently, the scouring process removed the wax from the surface of the fiber, since scoured cotton sinks in water in less than 1 minute. According to Piest (50) raw linters contain about 0.8 percent wax. They do not sink in the mixed acid used for nitration. Linters purified with dilute sodium hydroxide prior to nitration contained 0.1 to 0.3 percent of wax extractable with carbon tetrachloride or ether. The purified linters sank in about 30 seconds in mixed acid.

There seems to be considerable evidence favoring the idea that wax is removed during the alkaline kier boil by emulsification rather than by saponification (16). The presence of unsaponified wax esters in the kier boil liquors is cited as evidence of this. The alkali probably combines with the free fatty acids present in the wax to form a soap which promotes the emulsification of the rest of the wax. Soap is sometimes added to the kier solution to aid in the removal of wax, Addition of xylene or other fat solvents to the kier is also said to aid in the removal of wax (40).

Pectin: The typical, mature cotton fiber contains from 0.6 to 1.2 percent pectin according to the best estimates available. The amount reported depends on the method of determination. Extraction of the pectin from the fiber with hot ammonium oxalate or citrate solution, followed by precipitation as calcium pectate, gives values of about 0.7 percent (10, 28), while determinations based on the evolution of carbon dioxide from the uronic acid groups of the pectin when boiled with hydrochloric acid gives values of about 1.2 percent (30). Since it is difficult to extract pectin quantitatively from the fiber, the higher value obtained by estimation of uronic acids is possibly more nearly correct. Most of it is localized in the primary cell wall where it may be demonstrated by staining with ruthenium red (32). Available evidence indicates that it may occur in the fiber as insoluble calcium, magnesium and iron salts (66).

Pectic acid has been isolated from the cotton fiber (28) and identified by it specific rotation of +225.4° in 0.1N sodium hydroxide, titration equivalent of 201, carbon dioxide yield of 21.8 percent and mucic acid yield of 44 percent. These values are similar to those found for pectic acid from citrus fruits.

Pectin is probably a linear polymer of d-galacturonic acid residues of pyranose structure linked together in the 1 and 4 positions, as shown by the following formula:



Most preparations of pectin from citrus fruits or apples yield a few percent of d-galactose and l-arabinose on hydrolysis, but it is not established whether these compounds are part of the pectin molecule or come from accompanying galactans and arabans. Arabinose and xylose have been reported to be present in cotton fiber pectin (5). In undegraded pectins, most of the carboxyl groups occur in the form of methyl esters.

It has been suggested that pectin is the substance cementing the cellulose together in the cotton fiber (24), but this idea has not received acceptance or experimental verification. Practially all of the pectin is removed from the fiber by kier boiling; in fact boiling for one-half hour with 1 percent sodium hydroxide will remove pectin completely. It is not readily removed by water alone. Neither tensile strength nor fluidity in cuprammonium hydroxide (42) is greatly altered by the removal of pectin.

Pectic substances may be precipitated from the kier liquors by acidification (55). The material precipitated in this manner is brown in color and contains wax and protein, as well as pectin.

Protein: According to Ridge (52) the total nitrogen content of raw cotton of American origin is 0.21 percent of the air-dry weight, while Egyptian cotton contains 0.30 percent. If this is considered to be all protein nitrogen the values may be multiplied by the conventional 6.25 to give 1.3 and 1.9 percent protein, respectively. It is likely, however, that part of the nitrogen in the fiber is non-protein. The raw cotton fiber gives the xanthoproteic test with concentrated nitric acid followed by aqueous sodium hydroxide, and also Millon's reaction for tyrosine. The protein occurs chiefly in the lumen of the fiber where its location may be demonstrated by staining (23). The nitrogen is readily removed from the cotton by a mild alkali boil. As a means of controlling the scouring and bleaching operations analytically, the estimation of nitrogen is therefore, of little value. The nitrogen content of scoured cotton is about 0.035 percent.

The brown coloring matter of cotton and the dark brown color of kier liquors are associated with proteins in the discussions of a number of writers. This is, no doubt, due to the influence of the observation of Schunk (54) that brown materials containing 5 to 6 percent nitrogen could be obtained from kier liquors.

Little is known about the composition and properties of the protein of the cotton fiber, or about the nature of other nitrogenous constituents of the fiber. Leucine or tyrosine has been detected in the proteinaceous materia (54). Histamine has been isolated in crystalline form in extremely small

quantities from cotton dust collected from card-rooms in connection with investigations of the cause of "stripper's asthma" (29).

The protein of the cotton fiber appears to have only minor effect on the dyeing properties of cotton. High nitrogen content of finished fabrics due to poor scouring is said to favor damage by bacteria and molds (59). Yellowing of fabric on steaming has been ascribed to proteins (30), but is probably due to the presence of oxycellulose arising from over-bleaching.

Ash and its Constituents: A typical sample of raw cotton will contain about 1.2 percent of ash of approximately the following percentage composition: K_2O, 34; CaO, 11; MgO, 6; Na_2O, 7; Fe_2O_3, 2; Al_2O_3, 2; SiO_2, 5; SO_3, 4; P_2O_5, 5; Cl, 4; CO_2, 20; Cu, trace; Mn, trace (34, 43, 44). Variations considerably above and below these values are recorded in the literature. These large variations appear to be due to analysis of cotton containing sand, soil and dust, and to faulty methods. The variations in ash constituents arising from differences in soil, climate and kind of cotton are probably much smaller. Fargher and Probert (22) give the average ash content in percent of air-dry weight of combed raw cotton grown in different parts of the world, as follows: North American, 1.17; South American, 1.16; American Cotton grown in India, 1.25; American cotton grown in other countries, 1.47; Egyptian cotton, 1.20; Indian cotton, 1.28; Sea Island cotton, 0.98. Kearney and Scofield (36) found the average ash content of cotton taken from unopened bolls to be 1.17 percent of dry weight. The ash of cotton fiber is strongly alkaline, a property typical of plant ash. One gram of ash will neutralize 13 to 16 ml. of normal acid. About 85 percent of the ash may be removed from the fiber by extraction with water, but most of the calcium, iron and aluminum remain in the fiber (64). The ash content of cotton after scouring and bleaching is usually negligible. The fact that washing cotton with water greatly increases its electrical resistance by removing most of the soluble potassium and sodium salts made possible its adoption as a substitute for silk as textile insulation on telephone cords, wire, and cable (63).

Pigment: The nature of the pigment which is responsible for the faint creamy color of raw cotton is not known. According to Oparin and Rogowin (48) it is at least genetically related to chlorogenic acid, a condensation product of caffeic acid and quinic acid. It is possible that cotton fibers may contain some of the flavone pigments found in cotton flowers (60). Cotton fiber increases in color or chroma after storage periods of two to five years (46). Highly colored cottons are known, mainly brown and green.

Chemical Changes in the Developing Fiber: Cellulose has been detected microscopically in the two-day old fiber (62) and by x-ray analysis in the 6 to 10-day old extracted fiber (31, 58). However, during the elongation stage in the development of the fiber, the cell wall is composed chiefly of non-cellulosic substances such as pectin. The young 20 to 25-day old fiber contains about 6 times as much nitrogen (33) and about 3 times as much pectin (7, 65) as the mature fiber. At this stage the sugar content may be 25 to 55 percent on the dry basis (3, 8). The sugars found are glucose, fructose, and a pentose (9). Starch grains have been identified microscopically in the immature cotton fiber (1). The possible presence of nitrate and nitrite have also been suggested (33). Coincident with the start of thickening and

deposition of cellulose in the secondary wall at about the eighteenth day, the pectin, nitrogen and sugar contents of the fiber fall abruptly during a period of 10 to 15 days, approaching the composition of the mature fiber, and then slowly until the boll opens. Any condition that interrupts or hinders the process of development will result in the final fiber being thin-walled and high in pectin, nitrogen and sugar, and low in cellulose.

Relation between the Chemical Composition of the Fiber and Its Physical Properties: Nickerson, Fontaine, and Leape (47) have determined the various groups of constituents found in raw cotton on seven samples selected for different degrees of fineness. Their work is one of the few instances where most of the constituent groups for which methods are available have been estimated on the same group of samples. They found that wax, pectin, and nitrogen tended to increase in amount with increasing fineness of the fiber. Their data are given in the following table:

Table 3. Physical Characteristics and Chemical Constituents of Raw Cottons as Percentage of Dry Weight

Variety	Crop Season	Staple Length	"Fineness"[a] (cm./mg.)	Bundle Strength (lbs./sq.in.)	Wax	Pectate	Organic-Ammonia Nitrogen	Total Nitrogen	Phosphorus	Weight-loss During Kier-boil	Ash	Ash Alkalinity[b] cc. N/1 H_2SO_4
					%	%	%	%	%	%	%	
Half & Half	1937	7/8 inch	441	68,100±700	0.44	0.43	0.132	0.140	0.020	7.0	1.01	13.0
Rowden	1938	1 "	461	80,600±900	0.60	0.58	0.127	0.129	0.020	7.1	1.14	14.2
Wilds-5	1937	1-3/32"	565	82,300±900	0.70	0.60	0.147	0.144	0.020	7.8	1.11	14.6
Acala	1938	1 "	610	81,700±600	0.75	0.69	0.165	0.172	0.020	8.0	1.20	13.6
Express	1938	1-1/32"	621	80,500±800	0.90	0.77	0.168	0.168	0.019	8.2	1.17	14.8
Delfos	1938	1-1/32"	826	73,900±400	0.87	0.71	0.172	0.174	0.019	8.6	1.26	15.4
Sea Island	1938	1-1/4 "	847	96,000±1600	0.89	0.76	0.232	0.234	0.022	8.5	0.80	16.3

[a] The reciprocal of the more usual fiber-weight-per-centimeter.

[b] Defined as milli-equivalents of sulfuric acid required to neutralize 1 gram of ash.

Composition of Cotton Linters: In addition to the true fiber or lint, the cottonseed bears a large number of short hairs or fibers which are called linters or fuzz. These short fibers are removed from the seed after ginning and used as a source of chemical cellulose and for mattress filling. The composition of the fuzz fibers has not been thoroughly investigated but is presumably similar to that of the cotton fiber. The composition of crude commercial linters is greatly influenced by the presence of seed fragments, plant trash, and dirt. Munson (45) gives the following percentage composition of crude linters: Cellulose 80 to 85, ash 1.0 to 1.5, ether extract 1.0, lignin (H_2SO_4 insoluble) 3.0, iron 0.06, and moisture 6.0. Purified, dried linters had the following percentage composition: Cellulose 99.0, ash 0.1, ether extract 0.2, lignin 0.2 and iron 0.002. According to Rogers (53) the majority of samples of crude linters contain 72 to 77 percent cellulose on the "as received" basis when analyzed by the "pot-cook-yield" method. The accepted moisture content for linters is 8 percent (not regain). Piest (50) found the wax content of crude linters to be 0.87 percent by benzene extraction and 0.74 percent by ether extraction. The ash content was 2.4 percent. Purified linters had a wax content of 0.1 to 0.3 percent and an ash content of about 0.2 percent.

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CHEMICAL COMPOSITION OF COTTONSEED AND DERIVED PRODUCTS

Cottonseed as obtained from the gin is composed of the following physical parts: (1) the kernel or meat, which is the inner part of the seed; (2) the hull, which is a dark-colored shell surrounding the kernel; and (3) the linters, which are the short fibers attached to the hull and not removed in the ginning process. In processing cottonseed for oil, the seeds are delinted; the hulls are removed; and the oil is pressed from the cooked kernels. Cottonseed cake is the residue remaining after pressing out most of the oil from the kernels. Cottonseed meal is the ground cake.

The proximate composition and ash constituents of the whole seed, kernels, hulls, and meal, as summarized in Table 4, are compiled from analytical data reported by a number of investigators (14, 23, 24, 26, 27, 54, 84).*

* Literature citations on pages 31 - 38.

Table 4. Proximate Composition and Ash Constituents of Cottonseed and Derived Products

(Average Values for Air-Dry Material)

Constituent	Whole seed	Kernels	Hulls	Meal or cake
	percent	percent	percent	percent
Moisture	9.9	6.9	9.3	7.8
Oil	19.5	29.6	0.9	7.4
Protein (Nx6.25)	19.4	30.3	3.8	44.8
Crude Fiber	22.6	4.8	46.1	9.9
Ash	4.7	6.9	2.6	5.6
N. Free Extract	23.9	15.4	37.3	24.5
P_2O_5	1.27	1.73	0.25	2.88
K_2O	1.17	1.14	1.02	1.77
Na_2O	0.20	--	0.02	0.29
CaO	0.25	0.16	0.18	0.43
MgO	0.55	0.78	0.26	0.95
SO_3	0.12	0.12	0.08	0.19
Fe_2O_3	0.07	0.03	0.03	0.14
Cl	0.05	0.01	--	--
SiO_2	0.06	0.05	0.05	0.27
Mn	--	0.0013	0.014	--
Cu	--	0.005	0.0014	--
Zn	--	0.032	0.002	--
S (total)	--	0.36	0.04	--
F	--	--	12-14 p.p.m.	20-31 p.p.m.
I	--	--	--	23-1420 p.p.b.

The values for manganese, copper, zinc, and total sulfur are those of McHargue (54). Small amounts of iron, manganese, copper, boron, silicon, barium, aluminum, zinc, and nickel have been reported in "hull bran", a name used for the ground hulls after removal of most of the linters (57).

It must be kept in mind that the values given in Table 4 are substantially "average" values obtained by analysis of cottonseed and its products. Actual reported values are quite variable due to the influence of variety, stage of maturity, environment of production, and mode of processing. For example, the degree of completeness of the ginning operation or the separation of hulls from kernels will affect the analytical values, especially for oil, protein, and crude fiber.

LINTERS. Although linters are usually classed with cottonseed products, they are really cotton fibers, and their composition is discussed in the last section under "Chemical Composition of Cotton Fibers".

HULLS. The composition of cottonseed hulls is discussed below under "Carbohydrates of Cottonseed" and in other sections of the review.

COTTONSEED OIL. One of the most important products of the cottonseed is the oil which is obtained by pressing or extracting the cottonseed meats or kernels. It is composed principally of glycerides of several fatty acids, but may contain certain amounts of fatty acids freed by hydrolysis of these glycerides. The free fatty acids, as well as other objectionable constituents, are removed in the refining process which consists essentially of treating the crude oil with alkali, followed by bleaching and deodorizing.

Fatty acids in the oil. Hilditch and Maddison (37) determined the proportions of component fatty acids in a specimen of refined (but not deodorized) cottonseed oil by means of ester-fractionation. The percentages (by weight) of the acids which they reported are given in Table 5.

Table 5. Component Fatty Acids in Cottonseed Oil

Fatty acid	Percent
1. Linoleic	47.8
2. Palmitic	23.4
3. Oleic	22.9
4. Hexadecenoic	2.0
5. Myristic	1.4
6. Arachidic	1.3
7. Stearic	1.1
8. Tetradecenoic	0.1
	100.0

Glycerides in the oil. By means of systematic low-temperature crystallization Hilditch and Maddison (37) estimated the glycerides present in cottonseed oil to be as follows: 58 percent monosaturated (mainly palmito)-diunsaturated, 28 percent triunsaturated, 13 percent monounsaturated-disaturated and traces of tripalmitin. Of the main components, approximately 35 to 40 percent are probably palmito-oleolinoleins, with 20 percent or more palmito-dilinoleins and small amounts of palmitodiolein. Oleodilinoleins probably constitute almost all of the triunsaturated glycerides, although the possibility of the presence of small amounts of trilinolein is not excluded.

Tocopherols in the oil. Cottonseed oil contains approximately 0.1 percent of substances which retard the rate of oxidation and peroxide formation and help to prevent the development of rancidity. Two of these substances have been identified as alpha and gamma tocopherols and may be obtained from concentrates prepared by fractional molecular distillation of the oil (6, 67, 82). The vitamin E activity demonstrated for these concentrates is attributed to the tocopherols present (17, 45). The individual tocopherols have been separated from one another by chromatographic adsorption methods, and crystalline esters of these tocopherols have been prepared (6).

Tocopherols have been found in a large number of vegetable oils, but are generally absent in animal fats (30, 60). When added to animal fats that are exposed to air or oxygen, tocopherols are oxidized during the period in which they exert their antioxygenic action. The complete disappearance or oxidation of the tocopherols practically coincides with the end of the induction period of the fat, at which time there is a readily detectable increase in the rate of oxygen uptake and peroxide formation (31).

In the case of vegetable oils, such as cottonseed oil, the acceleration of peroxide formation does not occur until a considerable time after the total disappearance of tocopherol (30). This led to the discovery of antioxidants less susceptible to oxidation, which have been found in oxidized cottonseed and other vegetable oils (30). Golumbic (30) concluded that these antioxidants were probably chroman - 5, 6 - quinones or related compounds, but stated that the tocopherols were not their precursors. Recent work by Swift, Mann and Fisher (81) seems to establish the fact that gamma tocopherol is the precursor of these quinones. They are reported by Golumbic (30) to have no vitamin E activity, but to exhibit marked antioxygenic properties even in very low concentration. These substances, to the extent of about 0.02-0.03 percent, have been reported in hydrogenated vegetable fats oxidized to the total disappearance of tocopherol (30).

Sterols in the oil. The sterols, highly complex alicyclic alcohols, are present in the unsaponifiable portion of cottonseed oil in quantities as high as 1.6 percent of the oil (5, 48), although Jamieson and Baughman (44) report only 0.9 percent unsaponifiable matter in a typical Upland Type cottonseed oil. Beta-sitosterol ($C_{29}H_{49}OH$) is the sterol present in the largest amount. Stigmastanol ($C_{29}H_{51}OH$) has been isolated in less than 1 percent quantity from a fraction of crude cottonseed sterols (87). It has also been found in cottonseed meal in amounts approximating 0.01 percent of the meal (5). Approximately 0.9 g. of ergosterol ($C_{28}H_{43}OH$) was isolated from 45 g. of crude cottonseed sterols by Windaus and Bock (89). It was identified by mixed melting point, mixed melting points of derivatives, combustion analyses, and by antirachitic activity after irradiation with ultraviolet light. Recently, mixed sterol glucosides having the approximate empirical formula $C_{35}H_{60}O_6$ have been isolated from cottonseed oil (83). They are high-melting compounds (248° - 250° C.) which, upon acid hydrolysis, yield d-glucose and cottonseed sterols.

Other substances in the oil. Crude cottonseed oil contains, in addition to the aforementioned substances, numerous other constituents. The following substances have been identified and determined in the acetone-insoluble settlings from the crude oil (41, 43): starch and tannins (0.00%), proteoses

and peptones (+ test), wax (+ test), resins (considerable amounts), pentosans (1.74%), raffinose (4.20%), phytosterolin (0.1%), dipalmitin (1.1%), mucilaginous substances (small amounts), xanthophyll, carotene and chlorophyll (small amounts). It should be noted that some of the foregoing substances are probably present in the oil through lack of efficiency in cottonseed processing methods.

The acetone-insoluble settlings of crude cottonseed oil (0.1 - 0.2% of the crude oil) have been shown by analysis (42) to contain the following percentages of inorganic constituents calculated in the conventional manner: no chlorine, 0.60 silica, 6.14 phosphorus pentoxide, no sulfur trioxide, 0.26 calcium oxide, 1.46 magnesium oxide, 1.79 potassium oxide, 0.33 sodium oxide, trace of iron, and 1.71 nitrogen. Information on the presence and nature of sulfur and chlorine compounds in cottonseed oil is limited and conflicting. If they are present at all, they probably occur in very small amounts (16, 68).

Recently, the aliphatic hydrocarbon squalene ($C_{30}H_{50}$) was found to be present to the extent of 4 to 12 mg. per 100 grams of cottonseed oil (20). The hydrocarbon was isolated and identified as its hexahydrochloride.

Phosphatides, gossypol, vitamins and other substances present in the oil, as well as in the cake or meal, will be discussed individually or in connection with other constituents.

COTTONSEED PROTEINS. Considerable work has been done on the proteins and amino acids of the cottonseed. The proteins are usually extracted from the oil-free meal with water or various salt and alkali solutions and separated from the extract by dialysis, heat coagulation, dilution, or adjustment of the pH to the isoelectric point.

Two salt-soluble proteins (globulins) have been identified and determined (47) in the meal: (1) alpha-globulin, 2.59 percent; and (2) beta-globulin, 16.0 percent. In addition, 2.08 percent of a pentose protein has been reported (47) along with two phospho-proteins which were present in 0.83 percent and 2.54 percent quantities. An alkali-soluble protein, glutelin, has also been reported to be present to the extent of 0.73 percent (47).

Jones (46) suggested the factor 5.3 for use in converting percentages of nitrogen in cottonseed into terms of protein instead of the factor 6.25 commonly used in feed analysis.

Osborne and Voorhees (63) reported 15.83 percent of a salt-soluble protein in oil-free cottonseed meal, and named this protein "edestin". The name "edestin", however, is now applied exclusively to hemp-seed globulin. The amino acids obtained upon hydrolysis of the salt-soluble protein (globulins) of cottonseed (1) are given in Table 6.

Table 6. Amino Acids Obtained by Hydrolysis of "Edestin" (Globulins) of Cottonseed

Amino Acid	Wt. Percent
Glycine	1.2
Alanine	4.5
Valine	+
Leucine	15.5
Serine	0.4
Aspartic acid	2.9
Glutamic acid	17.2
Tyrosine	2.3
Phenylalanine	3.9
Proline	2.3
Tryptophane	+

The nitrogen distribution in cottonseed meal has been investigated by several workers (32, 34, 58). The data reported by Hamilton, Nevens and Grindley (34) are compared with the data of earlier investigators in Table 7.

Table 7. Nitrogen Distribution in Cottonseed Meal[a/] (Expressed as percentage of total nitrogen)

	Hamilton, Nevens, and Grindley (34)	Grindley, Joseph and Slater (32)	Nollau (58)
Ammonia N	9.41	10.45	14.06
Humin N	6.30	7.78	6.27
Arginine N	18.71	19.52	12.77
Cystine N	0.94	0.65	2.74
Histidine N	7.17	5.47	7.57
Lysine N	4.21	4.78	1.94
Amino N in filtrate from bases	40.72	42.82	45.02
Non-amino N in filtrate from bases	2.87	5.43	7.49
Nonprotein N	6.21	--	--
N lost in analysis	3.29	--	--
Total	99.83	96.90	97.86

a/ Cottonseed meal investigated by Hamilton et al. (34) contained 6.80 percent total nitrogen.

More recently, the globulins of cottonseed have been removed by alkali and salt extraction of cottonseed meal, and about 80 percent of the amino acids have been determined (21). These amino acids as reported by Fontaine, Olcott and Lowy (21) are given in Table 8.

Table 8. Amino Acids of Cottonseed Globulins

Acid	Prepared by Alkali Extraction	Prepared by Salt Extraction
	Wt. Percent	Wt. Percent
Arginine	11.5	13.6
Histidine	2.8	2.9
Lysine	5.4	4.9
Cystine	1.1	1.2
Methionine	2.5	1.7
Phenylalanine	8.1	9.1
Tryptophane	1.3	1.5
Tyrosine	3.5	3.2
Serine	2.9	2.9
Threonine	2.9	2.9
Leucine	8.5	8.4
Isoleucine	2.2	2.5
Valine	6.1	7.5
Dicarboxylic acids from NH_2-N	17.5	19.7

An additional amino acid, hydroxylysine, has been determined in cottonseed globulin by Van Slyke et al (86). They report 0.23 percent of the total nitrogen in this protein to be hydroxylysine nitrogen.

Investigations by Spies (80) and co-workers have led to the separation of allergenic proteins from cottonseed. Two active protein fractions (1 and 2) and a polysaccharidic protein fraction (3) have been analyzed for amino acids and other constituents. The three fractions contained 19.8, 20.2, 11.6 percent nitrogen; 2.29, 2.24, 2.04 percent sulfur, and 0.9, 0.9 and 36.6 percent carbohydrate, respectively, on an ash-free and moisture-free basis. The amino acid content of these fractions is given in Table 9.

Table 9. Amino Acid Content of Allergenic Protein Fractions from Cottonseed (Expressed as Percent of Total Nitrogen)

Nitrogen in the form of:	Protein fraction 1	2	3
Ammonia	15.0	14.9	9.9
Humin	0.1	0.1	1.1
Cystine	4.5	4.9	4.3
Histidine	0.1	0.1	---
Arginine	32.8	33.2	29.5
Lysine	3.8	1.6	2.0
Glutamic acid	14.2	14.2	11.4
Tyrosine	1.7	1.8	1.3
Monamino fraction	8.0	---	11.2
Dicarboxylic acid	3.5	---	7.4

CARBOHYDRATES OF COTTONSEED. The carbohydrate make-up of the cottonseed is quite complex. The trisaccharide raffinose ($C_{18}H_{32}O_{16}$) is the sugar which predominates in the kernel. According to Hudson and Harding (40) cottonseed meal is the cheapest and most convenient source of raffinose. An average of 6 to 8 percent of it is usually present in the meal (39, 40) or cake (8), as ascertained by polarimetric readings on cottonseed extracts. However, in commercial or laboratory preparation of pure raffinose from the meal, only 2 to 4 percent yields of the pure product are usually obtained (8, 19).

Mirer (56) analyzed the kernels of two grades of Transcaucasian cottonseed and found them to contain 13.15 and 14.08 percent of carbohydrates on a dry basis. The carbohydrate distribution in these two samples is given in Table 10.

Table 10. Carbohydrate Distribution in Kernels of Transcaucasian Cottonseed

Carbohydrate	Sample A Percent	Sample B Percent
1. Crystalline sugars (monosaccharides, hydrolyzed raffinose, sucrose, etc.)	7.29	7.90
2. Colloidal "sugars" (dextrins, soluble pectins, etc.)	0.41	0.65
3. Starch	None	None
4. Hemicellulose and pectin-like substances	3.30	3.36
5. Cellulose	2.15	2.17

Markley (51) analyzed cottonseed-hull bran and determined its various carbohydrate constituents. The bran gave a furfural yield of 25.33 percent, which corresponds to 49.24 percent pentose or 43.33 percent pentosan. An alcoholic extract of the bran, after hydrolysis, was found to contain 42.84 percent reducing sugars when calculated as dextrose, or 43.58 percent when calculated as xylose. This extract gave positive tests for dextrose and galactose, but a negative test for sucrose. The hulls contained 51.7 percent crude cellulose and 23.82 percent lignin (51). Upon chemical analysis the crude cellulose gave values of 18.78 percent pentosan, 23.70 percent alpha-cellulose, and 7.94 percent beta-cellulose.

Anderson and Kinsman (3) obtained 25 percent of hemicellulose from cottonseed hulls by extracting with sodium hydroxide or ammonium oxalate solutions. This hemicellulose yielded 74 percent l-xylose, 9.7 percent d-glycuronic acid, and 19 percent of unidentified substances. According to these investigators this hemicellulose had a molecular weight of 1800 - 2000. They identified an aldobionic acid in the hydrolytic products of the hemicellulose. On extraction with ammonium oxalate, cottonseed-hull bran yielded 38.7 percent pentosans, 38.4 percent l-xylose, and 5.3 percent d-glycuronic acid. On extraction with sodium hydroxide it yielded 10.1 percent pentosans, 10.1 percent l-xylose, and 1.45 percent d-glycuronic acid (3).

PHOSPHATIDES. The phosphatides (or phospholipids), lecithin and cephalin, occur in both crude cottonseed oil and cottonseed meal. According to Goldovskii and Lishkevich (28) only about 10 percent of the phosphatides in cottonseed occur in the oil removed in processing, the remainder being present in the cake. Lecithin usually constitutes about one-third of the phosphatides and cephalin the other two-thirds (72). Crude cottonseed oil usually contains from 1.5 to 1.8 percent of these substances (29). Considerably higher amounts are reported to occur in the seedlings than in the seed (52).

Lishkevich (50) separated the phosphatides from cottonseed into three fractions: acetone-soluble, 16.5 percent; ethyl alcohol-soluble, 76.5 percent; and benzene-soluble, 7.0 percent. The acetone-soluble fraction contained 46.2 percent lecithin and 53.8 percent cephalin. The ethyl alcohol-soluble fraction consisted of 53.2 to 59.4 percent lecithin and 40.6 to 46.8 percent cephalin. The benzene-soluble fraction was practically all lecithin. The component fatty acids in cottonseed phosphatides as reported by Hilditch and Zaky (38) are given in Table 11.

Table 11. Component Fatty Acids of Cottonseed Phosphatides

Acid	Percent
1. Palmitic	17.3
2. Stearic	7.3
3. Arachidic	2.8
4. Hexadecenoic	1.5
5. Oleic	20.3
6. Linoleic	44.4
7. Unsaturated (C_{20-22})	6.4

Fraps (22) reported that cottonseed meal contains about 0.26 percent of choline and betaine, and Maxwell (53) observed the relative proportions of choline and betaine in cottonseed cake to be 1:4.7. Engel (18) reported contents of choline (as milligrams of choline chloride per gram of dry material) to be as follows: two samples of cottonseed meal 3.76, 3.51; cottonseed kernels 3.19.

PHYTIN. Rather (71) reported that the phosphorus of phytin represents about 72 percent of the total phosphorus present in cottonseed meal, and that the phytin phosphorus contents of two samples of meal were 0.76 and 0.86 percent. From a single sample of meal, Rather (70) obtained approximately 1.4 percent of a tristrychnine derivative of inositol phosphoric acid. He identified inositol triphosphoric acid, as well as inositol pentaphosphoric acid, in some meals (70). Rather, in disagreement with Anderson (4), found no inositol hexaphosphoric acid in cottonseed meal.

Phosphorus in the form of phytin or related compounds is generally considered to be poorly available from a nutritional standpoint, although there seems to be some controversy about this topic (9). Information concerning these phosphorus compounds of cottonseed products is therefore deemed important.

OTHER PHOSPHORUS COMPOUNDS. A small proportion of the phosphorus occurs in cottonseed as phosphoproteins and insoluble substances (49). There seems to be some controversy as to whether or not meta or pyro phosphoric acids are present (35, 69).

PHOSPHORUS DISTRIBUTION. Of the phosphorus present in the important oil seeds, 52 - 76 percent is reported to be phytin phosphorus, 1.4 - 8.3 percent to be phosphatide phosphorus, and the balance to occur in phosphoproteins and insoluble matter (49). According to Lishkevich (49), the cottonseed seems to be higher than the other oil seeds in total phosphorus, phosphatides and phytin phosphorus.

GOSSYPOL. Probably the most important and most widely investigated pigment found in cottonseed is the phenolic compound, gossypol ($C_{30}H_{30}O_8$). An average of 0.05 percent of gossypol occurs in crude cottonseed oil (74). Larger amounts, 0.4 to 1.2 percent, have been found in the kernels and hulls (10, 76, 90).

Gossypol is usually separated from cottonseed oil or the diethyl ether extract of the meal by precipitation as the hexa-acetate or the dianiline derivative from which the free pigment can be liberated (10, 12).

If appreciable amounts of "active" gossypol are present, the pigment presumably gives toxic physiological effects. The heating used in modern methods of pressing the oil from the kernels renders the gossypol "inactive" (11), and commercial cottonseed meal and cake are therefore nontoxic feeds. According to an hypothesis by Clark (13), the reason for the decrease in toxicity upon heating or cooking and pressing is that the resin glands containing the gossypol are disrupted, much of the gossypol dissolves in the oil, and the pigment comes in contact with free amino groups of the proteins with the result that it is bound to other compounds and rendered physiologically inert.

Along with resinous compounds, gossypol contributes to the high color observed in crude cottonseed oil. The color is deepened in proportion to the concentration of gossypol present (64). It is believed by some investigators that there may be several forms of gossypol which are perhaps isomeric. They give similar chemical reactions, but vary in color from yellow to red and may give different absorption spectra; one form may presumably change to another form if the solvent medium is changed (10, 65). The fact that red gossypol is presumably a mixture of yellow gossypol and "gossypurpurin" (7) may help to explain these phenomena. Gossypol is reactive and unstable, and is therefore best studied by means of pure derivatives of the pigment (10).

Purified gossypol has been shown to have marked antioxidant properties at low concentrations. It is important also in that its presence during the processing of cottonseed reduces the refining losses of the oil (73, 75). After lengthy studies, Adams and co-workers (2) tentatively proposed that gossypol is: 2,2-bi-1,6,7-trihydroxy-3-methyl-5-isopropyl-8-aldehydonaphthyl. The work of these and other investigators has been reviewed by Haworth (36).

ENZYMES. The natural catalysts known as enzymes play an important role in many metabolic processes in plants. Each enzyme has the property of bringing about certain specific transformations. By utilizing this specific catalytic property of the enzyme, its activity in plant extracts can be determined.

Lipase. It has long been known that the enzyme lipase is responsible for hydrolyzing the esters of fatty acids to produce free fatty acids, but until recently (59) no such enzyme was found in cottonseed. Lipase is reported to be present in germinating cottonseed, but is not detectable in dormant seed (59). The lipolytic activity of preparations from germinated cottonseed proved to be equal to that of commercial pancreatin, and one-fourth to one-tenth as great as castor bean preparations which are known to be high in lipase content (59).

Catalase. The enzyme catalase, which characteristically liberates oxygen from hydrogen peroxide, was found to be rather abundant in cottonseed (61). The relative catalase activity constants of some of the substances studied were: beef liver, 5000; cottonseed, 600; soybeans, 15; and rape seed, 1.

VITAMINS. In addition to carbohydrates, fats, proteins, and minerals, there are certain accessory factors that are nutritionally essential if a satisfactory diet is to be maintained. These essentials have become known as vitamins. The vitamins reported in cottonseed and its products are as follows:

A - Cottonseed meal and oil are generally considered to be poor in this vitamin (15, 25). There is usually less than 1 Sherman-Munsell unit of Vitamin A per gram of meal (25). The ratio of A in butter and cottonseed oil is roughly 10 to 1 (15).

B_1 and G (B_2) - Cottonseed meal and flour are good sources of these vitamins, but the hulls contain no vitamin B_1. The meal or flour usually contains from 3 to 5 International Units of B_1 and G per gram (77, 78, 79). A third factor of the B complex is indicated in the hulls, although no B_1 was found (88).

D - Cottonseed oil contains ergosterol which on irradiation has vitamin D activity. A crude sterol fraction from cottonseed oil was found to contain 5 percent of pro-vitamin D (89).

E - Concentrates obtained from cottonseed oil by fractional molecular distillation have marked vitamin E activity (17, 60). The activity of 1.8 mg. of dl-alpha-tocopherol was found to be the same as that of 9.5 mg. of a cottonseed oil concentrate and slightly greater than that of 0.8 g. of cottonseed oil (17). The relative biological potencies of alpha- and gamma-tocopherols (from cottonseed oil) and beta-tocopherol (from wheat germ oil) are 1.0, 0.083 and 0.4, respectively (45).

OTHER SUBSTANCES. Numerous other substances have been reported to be present in cottonseed. Among those which could not be discussed conveniently under preceding headings are the following:

Saponins. These foam-producing glucosides, whose aglucons are usually sterols or related compounds, have been found in cottonseed meal (55).

Lactic acid. This acid, in the form of the magnesium salt [$Mg(C_3H_5O_3)_2 \cdot 3H_2O$], has been reported in the seed (85).

Tannins. Seven percent of tannins have been found in ripe cottonseed hulls (91).

Pigments. Cottonseed is reported to contain small amounts of water-soluble red-violet and violet pigments (33). Podolskaja (66) isolated a violet water-soluble pigment and concluded that it belongs to the anthocyanin group. Oparin and Rogowin (62) found small amounts of chlorogenic acid in cottonseed.

Boatner (7) reported that cottonseed contains at least three pigments in addition to gossypol: (1) a red oxidation product of gossypol, (2) a yellow oil-soluble pigment, and (3) a purple pigment which she named "gossypurpurin". According to this investigator the red gossypol of Podolskaja (65) is a mixture of yellow gossypol and the purple pigment. The blue pigment of Podolskaja (66) is claimed by Boatner (7) to be a compound or compounds of gossypol and gossypurpurin with protein.

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CHEMICAL COMPOSITION OF PEANUTS

The peanut is an annual herbaceous plant belonging to the Papilionaceae, a sub-order of the larger order Leguminoseae. The stem grows to a length of one to three feet and bears pinnate leaves similar to the clover but with four leaflets. Before the leaves develop, yellow sterile flowers appear on the stem and soon die. Later the plant bears smaller flowers which are nearly hidden by the foliage. After fertilization, the true peduncle develops and grows to reach the soil and push the "peg" three or four inches below the surface where the pods are formed. The pods are about 1/2 to 3 inches in length and roughly cylindrical. The important types grown in this country are the Virginia, the Runner, and the Spanish. Culture and marketing practices have been described by Lynch (57)*, in U. S. Department of Agriculture Farmers' Bulletin Number 1127 and in a number of State Agricultural Experiment Station Bulletins.

Several useful materials are obtained from different parts of the peanut plant. The dried vines are frequently used for hay. Such hay is about equal to soybean or cowpea hay in feeding value though lower in proteins (66). The fruit is a pod containing from one to several seeds. The shell of the pod comprises from 20 to 30 percent of the whole "nut" and may be easily separated from the kernels. The kernels themselves are enveloped by a thin red-brown, purple, or white skin called the testa.

Most of the large-seeded (Virginia and Runner) and some of the small-seeded (Spanish) peanuts are shelled on a large scale in shelling plants, though peanuts in the shells are also a considerable item of commerce. Sometimes after shelling the germs are removed from the kernels to improve the flavor. The kernels or meats are consumed in large quantities as roasted and salted nuts, in confections, cakes and biscuits and as peanut butter.

The broken pieces of nuts, shriveled kernels, meats considered below grade, germs of peanuts used for food, and the remainder of the crop, still in the shell, goes to oil mills. Here the pods are cleaned by means of reels, shakers, air blasts, etc., and cracked by machinery. The shells are separated from the meats and ground to make hull bran or used as fuel in the boilers of the mill. The kernels are rolled and pressed to remove the oil. Some mills use expeller presses while others use hydraulic presses. In the first case, the rolled meats are only slightly heated in a steam-heated conveyor which carries them to the press. When hydraulic presses are used, the rolled meats are first conveyed to the cooker where they are heated with steam in order to further break up the oil cells. The cooked meats are then formed into cakes, wrapped in hair filter cloths, stacked in the presses and subjected to high pressure. The cake remaining after the removal of the oil still contains from 5 to 9 percent of oil. It is ground to meal, blended with hull bran to adjust the protein content and used as stock feed. Some peanut meal is also used as fertilizer.

The kernel and press cake, the oil, the testa, and the shells will be considered separately in discussing the composition of the peanut, inasmuch as they are usually separated in common manufacturing procedure.

* Literature citations on pages 53 - 59.

PEANUT KERNEL AND PRESS CAKE. Numerous analyses have been reported on peanut kernels, starting about 1880 and continuing to the present. Most of these give only the usual feeding-stuff data. Table 12 gives high and low values of a number of investigators (19, 28, 60, 61, 66, 74, 90) while Table 13 gives average values of a number of samples of kernels from the 1942 crop of Spanish, Runner, and Virginia peanuts (80).

Table 12. Composition of Peanut Kernel

Reported by	Moisture	Protein	Ether Extract	Crude Fiber	N-Free Extract	Ash	Reducing Sugars	Disaccharide Sugar	Starch	Pentosans
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Fraps (19)	7.42	35.25	54.15	4.26	21.20	3.05	0.28	5.21	3.18	2.72
	4.00	24.10	40.86	2.06	6.02	1.82	0.06	2.31	0.94	2.20
Winton (90)	13.15	31.12	50.22	3.04	19.04	3.06				
	3.87	25.75	35.77	1.18	9.39	1.90				
Sah et al. (74)		36.38	53.72							
		29.04	51.13							
Morgaillon (60, 61)	6.10	24.5	43.6	2.6	24.85	2.65				
	5.05	21.0	42.1	1.9		1.88				
Higgins et al. (28)		32.88	51.91	3.30				3.75	5.32	
		27.63	43.02	2.05				1.88	1.98	
Morrison (66)	5.3	30.5	47.7	2.5	11.7	2.3				

Table 13. Mean Results of Peanut Analyses for 1942[a]
(Moisture-free basis)

	Number of Samples	Petroleum Ether Extract	Nitrogen	Nitrogen (Oil Free Basis)	Protein[b] (N x 5.46)	Iodine No. of the Oil (Wijs)	Free Fatty Acid of the Oil
		Percent	Percent	Percent	Percent		Percent
Spanish	172	50.8	4.93	10.01	26.92	95.7	0.4
Runner	123	50.3	4.84	9.74	26.41	91.6	0.65
Virginia	84	48.4	4.77	9.27	26.05	93.6	0.3

[a] Based on analysis of Agricultural Marketing Administration Samples (80).

[b] This factor suggested by Jones (44) because most of the nitrogen is present as arachin and conarachin, both of which contain 18.3% nitrogen.

These values indicate that the peanut kernel will generally consist of approximately the following: 50 percent oil, 30 percent protein, 3 percent crude fiber, 3 percent ash, and 14 percent nitrogen-free extract. Since most of the oil is removed in pressing, the cake should contain almost twice as much protein, crude fiber, ash, and nitrogen-free extract as the kernel. However, commerical peanut meal actually contains slightly more ash and crude fiber but less protein than the original oil cake because some hull bran is usually added when the cake is ground.

Protein: As early as 1880 Ritthausen (73) isolated a globulin from peanuts. His yield was about 25 percent of the meal. Proteins from peanut kernel were further investigated in 1913 by Iaichnikov (37) who found that out of 9.1 percent nitrogen in peanut material (possibly meal) as much as 8.74 percent occurred as albuminous substance including albumin, gluten and globulin. In 1916 Johns and Jones (42) isolated and described two globulins which they named arachin and conarachin. About one fourth of the protein was conarachin which is much more soluble than arachin. When separated from a salt solution by precipitation with ammonium sulfate, or by dilution with water, arachin settles out as a sticky, heavy precipitate. It may be obtained as a fine white powder by dehydration with alcohol and ether. On heating a neutral 10 percent sodium chloride solution of arachin, a slight cloudiness appears at 90° C. but no precipitate is formed even on boiling. However, if a small amount of acetic acid is added to the hot solution, a heavy precipitate is formed. The specific rotation of arachin in 10-percent sodium chloride solution is $(\alpha)_D^{20} = -39.5°$ (46). The isoelectric point is pH 5.1 - 5.2 (83). Tayeau (83) reports that arachin can be fractionated by precipitating with different concentrations of ammonium sulfate. He suggests the presence of glucides and lipides in preparations of arachin made in the usual manner.

Eirich and Rideal (15), using a special ultra centrifuge, separated the globulin arachin into 5 groups with molecular weights of 600,000; 400,000; 140,000; 30,000 and 20,000.

A solution of conarachin in 10-percent sodium chloride flocculates at 80° C.; its specific rotation is $(\alpha)_D^{20} = -42.7°$ (46); and its isoelectric point is pH 3.9-4.0 (83). Conarachin contains about three times as much sulfur as does arachin (1.09% for conarachin and 0.4% for arachin) (42). Its basic nitrogen content (6.55 percent) is among the highest found in seed globulins. Jones and Horn (46) reported that oil-free peanut meal contains 23.8 percent arachin and 8.7 percent conarachin. They also obtained a very small yield of an albumin coagulating at 65° - 70° C. Reports of numerous investigations on the nitrogen distribution and the amino acid content of peanut protein, using both the Van Slyke method and the direct method of Kossell and Kutscher, may be found in the literature. Some of these values are shown in Table 14 (90, 67) and Table 15 (42).

Table 14. Nitrogen Distribution in Peanut Protein[a]

	Johns and Jones		Dowell and Menaul	Nollau
	Arachin	Conarachin	"Protein"	
	Percent	Percent	Percent	Percent
Humin N adsorbed by lime	0.57	0.65)	1.2	4.36
Humin N in amyl alcohol extract	0.43	0.13)		
Cystine N	0.74	0.75	0.77	0.81
Arginine N	23.77	25.78	17.57	20.82
Lysine N	5.22	6.35	6.22	5.31
Histidine N	2.78	2.72	1.88	6.13
Amino N of filtrate	53.30	50.23	61.25	52.36
Nonamino N of filtrate	1.65	1.94	1.67	1.40
Amide N	11.81	11.08	11.48	10.93
	100.27	99.63	102.04	102.12

[a] Winton (90) Volume 1, page 508

Table 15. Amino Acids in Peanut Globulins[a]

	Arachin		Conarachin	
	Wt. Percent		Wt. Percent	
Glycine	0.00			
Alanine	4.11			
*Valine	1.13			
*Leucine	3.88			
Cystine	1.08	1.51	3.00	2.92
Aspartic Acid	5.25			
Glutamic Acid	16.69			
Tyrosine	5.50			
*Phenylalanine	2.60			
Proline	1.37			
*Tryptophane	0.88		2.13	
*Arginine	13.51		14.60	
*Lysine	4.98		6.04	
*Histidine	1.88		1.83	
Ammonia	2.03		1.90	
*Methionine	0.50	0.67		2.12
*Threonine		2.56		2.02
Serine		5.20		4.99
Hydroxylysine		0.01[b]		

* Nutritionally essential.

[a] Bibliography references 42, 43, 45, 46, 85.

[b] Calculated to weight percent from percent of total nitrogen.

The nutritional importance of a protein depends on its digestibility, nutritional efficiency, and content of the nutritionally essential amino acids. The coefficient of digestibility of peanut protein is given by Morrison (66) as 89 percent. This compares favorably with other legume and cereal proteins. Feeding experiments (43) indicate that arachin is deficient in tryptophane and methionine and also in a third factor, possibly isoleucine. Peanut meal has been reported to contain 1.67 wt. percent of isoleucine (51). Conarachin, on the other hand, according to Baernstein (3) is an excellent protein for growth when fed as the only source of protein. Baernstein also found that whole defatted peanut kernel, total peanut protein, or total peanut globulin is approximately equivalent to casein in promoting growth. These feeding studies, as well as the values given in Table 15, show that the protein in the peanut is an excellent source of the essential amino acids.

Inasmuch as 87 percent of the nitrogen of the peanut is present as arachin and conarachin, both of which contain 18.3 percent nitrogen, Jones (44) points out that the factor for converting percent nitrogen to percent protein should be 5.46.

Mineral Constituents: As previously noted, the ash content of the peanut kernel is not high, most reported values being between two and three percent. Major constituents of the ash of peanut kernels are shown in Table 16 (5, 9, 19, 48, 92).

Table 16. Minerals in the Peanut

	In Kernel		In Ash	
	Percent		Percent	
Potassium	0.68	0.89	30.8	39.6
Sodium			2.1	2.5
Calcium	0.02	0.08	2.6	3.4
Magnesium	0.09	0.34	8.7	9.0
Phosphorus	0.25	0.66	12.7	17.0
Sulfur	0.19	0.24	4.2	4.7
Chlorine			0.35	
SiO_2	0.08		0.2	0.4
Zinc (6) (7)	0.0017		0.078	
Manganese (71)	0.0008			
Iron (78)	0.0018			
Cobalt (1)	0.00003			
Copper (53, 71)	0.0007	0.0020		
Boron (55)	0.0026			
Fluorine (58)	0.00014			

As usual in plant ash, the potassium content is relatively high and the sodium content fairly low. From a dietary view-point the peanut is deficient in calcium but adequate in magnesium and phosphorus. Several important trace elements, such as zinc, copper and iron are also present in the whole peanut. Wolf (92) states, however, that peanut oils rarely contain zinc. Jodidi (41) found considerable variation in amount of ash from peanuts raised on different

types of soil, but very little work has been done in connection with variation of individual constituents as influenced by variety, maturity and environment.

Carbohydrates: The starch content of the peanut has been reported to be from about 0.5 percent to about 5 percent (41, 19, 28). The higher starch values, in general, have been determined as glucose after acid hydrolysis, and are therefore questionable. Although the starch content of the peanut varies with type, growing conditions, and maturity, it is probably slightly over 1 percent. Sucrose (10, 52) has been reported to constitute from about 4 to 7 percent of peanuts and Lamy-Torrilhon (52) suggested peanut cake as an industrial source of sucrose, describing a rather ingenious system for separating both the oil and the sugar from the cake by use of alcohol.

The phenylosazone of galactose was obtained by Traetta-Mosca (82) by reacting a water extract of peanuts with phenylhydrazine. According to Miyama (64) the pectic substance of the peanut is a galactoarabanpectic acid complex. Hirst and Jones (34), however, found no galactose or galactans in this fraction. After removing the oil and protein from ground peanuts, they extracted the crude carbohydrate mixture with hot dilute alkali which dissolved most of the pectic complex, leaving the starch and cellulose. This complex, they found, is a mixture of two components, araban and pectic acid, which they separated by lengthy extraction with aqueous alcohol. They found that the araban is identical with that obtained from the pectic material of the apple. Peanut kernels were found to contain 3.95 percent pectin (2) when analyzed by the method of Whistler, Martin and Harris (87).

Hirst and Jones (34) isolated 2 percent of cellulose from testa-free peanut kernels. This cellulose gave crystalline glucose in almost quantitative yield on hydrolysis. It dissolved in cuprammonium solution and gave quantitatively on acetylation a cellulose acetate having $(\alpha)_D^{20} = -10°$ in chloroform containing 10 percent of alcohol. Wittman (91) found 4.12 percent pentosans in the seed.

Other Constituents: Choline was isolated from the peanut by Schulze (75). Engel (16) pointed out its importance as a nutritional factor and reported the content of choline as choline chloride in milligrams per gram of dry material to be as follows: edible peanut meal 2.52, peanut meal (6 percent fat) 2.44, Spanish peanuts 1.74, Runner peanuts 1.65, and peanut butter 1.48.

Mooser (65) isolated an alkaloid from the peanut which he termed arachine. Reports of the presence of ricin (49, 77) in peanuts were apparently due to the European practice of pressing both castor beans and peanuts in the same establishment.

The phosphatides, lecithin and cephalin, were found to the extent of 0.5 percent by Higgins et al. (28), who also found that practically all the phosphorus in peanuts is phytin phosphorus. Other workers have found about half of the phosphorus to be phytin phosphorus (63). Since the nutritional value of phytin phosphorus is questionable, the presence of phoshorus in the form of phytin should be given consideration in all feeding tests with peanuts and peanut meal.

Peanuts contain practically no vitamins A, C, or D (70) though spectrophotometric curves of the crude oil show a broad band possibly due to carotinoids (2). This band is absent in refined peanut oil. The kernels are an excellent source of riboflavin (200 Sherman units per 100 g.), thiamin (about 1,000 micrograms per 100 g.), and nicotinic acid (20 milligrams per 100 g.) (8, 24, 79). They also are reported to contain considerable vitamin E. Analysis of peanut oil for tocopherol (2) gave values of 0.03 to 0.05 percent. Appreciable amounts of the members of the B complex, other than riboflavin, thiamin, and nicotinic acid, and vitamin K (70) are probably present although quantitative figures are lacking.

The presence of three enzymes has been established. Both soluble and insoluble catalase were found in peanuts by Loew (56). An active lipolytic enzyme, different from that of the castor bean, was found by Dunlap and Seymour (13) in sprouted peanuts, but under the conditions of their investiation was not active in dormant seed; this enzyme was also investigated by Fernandez and Pizarroso (17). The presence of an enzyme which hydrolyzes glucosides was shown by Leoncini (53). Carotene oxidase, the carotene-bleaching enzyme, is probably also present (2).

It is worth noting that Payen and Henry (69), in 1825, stated that calcium malate occurred in peanuts. Their evidence, however, is doubtful.

PEANUT OIL. The oil obtained by pressing peanut kernels can be used for soap stock (57) after filtration. Peanut oil is refined, however, for most food uses such as for cooking oil, hydrogenated fats, salad oil, and the production of oleomargarine. The refining process consists of treatment with alkali, bleaching and deodorizing. The resulting product is a light colored, odorless and tasteless oil. Subjected to these same treatments, very different crude oils lose their characteristic flavors, becoming so bland that it is very difficult to differentiate between well-refined corn, cottonseed, and peanut oils (57).

Considerable controversy exists in the early literature (11, 12, 14, 26, 27, 31, 35, 36, 38, 39, 40, 54, 62, 76, 84, 86) regarding the acids that make up the glycerides of peanut oil. The presence of each of the acids shown in Table 17 has now been well established (30, 32, 39, 89).

Table 17. Composition of Peanut Oil[a/]

Glycerides	Variety Unknown (30)	Spanish (39)	Virginia (39)	Senegalese (32)	West Africa (32)
	Percent	Percent	Percent	Percent	Percent
Oleic $C_8H_{17}CH:CH(CH_2)_7COOH$	55.7	52.9	60.0	65.7	71.5
Linoleic $CH_3(CH_2)_4CH:CHCH_2CH:CH(CH_2)_7COOH$	25.9	24.7	21.6	19.2	13.
Palmitic $CH_3(CH_2)_{14}COOH$	8.3	8.2	6.3	7.2	6.
Stearic $CH_3(CH_2)_{16}COOH$	3.1	6.2	4.9	2.6	3.
Arachidic $CH_3(CH_2)_{18}COOH$	2.4	4.0	3.3	2.6	3.5
Behenic $CH_3(CH_2)_{20}COOH$	3.1	-	-	-	-
Lignoceric $CH_3(CH_2)_{22}COOH$	1.1	3.1	2.6	2.6	3.
Unsaponifiable material	0.4	0.2	0.3	-	-
	100.0	99.3	99.6	99.9	100.0

a/ Calculated as simple triglycerides. Other acids probably present include: Caprylic, Lauric, Myristic, and Hexacosanoic.

Among other acids which have been reported and later proved to be absent may be listed isobehenic, hypogaeic, daturic (a mixture of palmitic and stearic), physetoleic and heneicosanoic.

The glyceride analysis of vegetable oil is complicated and difficult. Only approximate figures have been obtained so far. According to Hilditch (29), peanut oil contains negligible proportions of fully saturated component glycerides. Tri-C_{18} glycerides, which are probably 90 percent oleo-linolein and 10 percent stearodioleins, make up 56 - 57 percent of the oil. Triolein is not present in any great amount. The remainder of the oil consists almost wholly of monosaturated-diunsaturated glycerides. Later, using solvent fractionation and elaidinisation, Gunde and Hilditch (25) found the following approximate composition expressed on a molar basis for the glycerides of peanut oil: oleodisaturated, about 1 percent; monosaturated-dioleins, 11 percent; monosaturated-oleo-linoleins, 45 percent; linoleodioleins, 24 percent; and triolein, 19 percent. They calculated that the combined molar proportions of the individual saturated-acyl dioleins plus saturated-acyl oleo-linoleins in peanut oil are approximately: palmito - 30 percent, stearo - 11 percent, arachido - 6 percent, beheno - 7 percent, and lignocero - 2 percent.

The phosphatides, lecithin and cephalin (21, 28), are usually found in the sludge which settles out of the oil. The peanut oil phosphatides have not been thoroughly investigated, but Revald (72) reports that they contain a certain amount of carbohydrate, mostly disaccharides, which is very difficult to remove. He found that the phosphatides from the peanut oil contain almost twice as much cephalin as lecithin.

Antioxygenic constituents are also present in the oil (4, 22, 68) though most of these materials remain in the cake according to Hilditch and Paul (31). They are tocopherols and related compounds. It is interesting to note that the addition of more tocopherol than is normally found (0.03 to 0.05 percent) in the oil not only fails to increase the antioxygenic qualities but actually increases the tendency toward oxidation (4, 23). Maximum stability is exhibited at a concentration of about 0.05 percent tocopherol.

Marcelet (59) has reported the presence of 1.8 grams of higher hydrocarbons per ton of peanut oil. He isolated $C_{15}H_{30}$ and $C_{19}H_{38}$, both of which in concentrated form had an acrid nauseous taste. The characteristic odor and flavor of peanut oil are attributed by Marcelet to the presence of extremely minute quantities of these hydrocarbons. Taufel and Heimann (81) found squalene in peanut oil. Fitelson (18) isolated squalene from eleven samples. He found from 13 to 49 milligrams per 100 grams of oil.

Klostermann and Opitz (47) reported 247.9 milligrams of phytosterol per 100 grams of oil; most of it, 192.1 milligrams, was free and the remainder was present as esters. This makes up the greater portion of the unsaponifiable material.

TESTA (KERNEL SKIN). Konig (48) reports the average composition of the red skin of the peanut given in Table 18. These values indicate that it is high

Table 18. Average Composition of Red Skin of the Peanut

Constituent	Percent
Water	9.01
Albuminoids	12.68
Fat	11.76
Nitrogen-free extract	20.46
Fiber	34.90
Ash	11.19

in fiber and ash and contains appreciable fat and nitrogenous material. Fuchs (20) found 17 percent protein and 18 percent ether extract, but probably pieces of kernel were included. Pickett (70) found the red skins contained about 7 percent tannins. The skins from the white varieties of peanuts were, however, practically free of tannins. Booher (8) reported the red skins contain 7.9 milligrams of vitamin B_1 or thiamin per 100 grams. Pickett (70) also found that the B_1 content of the testa of the peanut is very high, exceeding any other foodstuff so far reported except possibly brewer's yeast.

PEANUT SHELLS OR HULLS. Approximate analyses of peanut hulls have been published by several investigators. White (88), Fraps (19) and Brown (9) give the values shown in Table 19. Analyses of hull ash are shown in Table 20 (9, 19).

Table 19. Proximate Composition of Peanut Hulls
(Average Values on Dry Basis)

	Protein	Ether Extract	Crude Fiber	N-Free Extract	Ash	Reducing Sugars	Disaccharide Sugars	Starch	Pentosans
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Spanish (88)	7.19	2.08	71.78	14.32	4.63				
Georgia (88)	4.99	2.12	79.30	10.59	3.00				
Texas (19)	7.31	1.19	65.73	21.22	4.53	0.59	1.72	0.74	17.82
Texas (19)	6.70	1.42	69.88	17.79	4.31				

Table 20. Analysis of Hull Ash

	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Sand	Undetermined
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Tennessee (9)	31.78	7.35	27.01	12.60	5.63	8.89	14.13		2.11
Texas (19)	27.68		7.40	5.97	3.57			42.73	12.65

Although the hulls have little food value, they are used to some extent as a filler or roughage in cattle and poultry feeds. Considerable quantities of ground hulls have been added to fertilizers as a filler or dilutent. Since the hulls have a high fiber content, it has been suggested (57) that they be used to make paper board, in the preparation of magnesia tiles and plaster, and as a substitute for cork in insulation.

Xylose can be produced from the pentosans in peanut hulls, but oat hulls and cottonseed hulls are both better sources of xylose. The cellulose content of peanut hulls is high. Since the cellulose is easily isolated (57), peanut hulls offer a source of cellulose for plastics at relatively low cost.

Fraps (19) reported that peanut hulls on the dry basis average 0.59 percent reducing sugar, 1.72 percent disaccharide sugar, 0.74 percent starch and 17.82 percent pentosans. The Whistler-Martin-Harris (87) method for uronic acids showed 6.94 percent in a sample of peanut hulls (2).

Kryz (50) extracted a reddish brown coloring matter from the testa with hot water, absolute alcohol, amyl alcohol, and benzine. He described its reactions with a number of reagents without giving conclusive results.

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CHEMICAL COMPOSITION OF SWEETPOTATOES

The sweetpotato (Ipomea batatas), believed to be a native of South America, is now cultivated throughout the tropics and sub-tropics, and in some temperate regions. It can be grown as far north as southern New England, but its successful cultivation is limited to warmer climates. There are two types based on condition after cooking: the mealy or dry sweetpotato commonly having light-yellow flesh, which is preferred in the North; and the soft or moist sweetpotato having light-yellow to deep orange flesh, especially rich in sugar, which is preferred in the South. The sweetpotato is often erroneously called yam, which is properly the edible root of a tropical plant of the genus Dioscorea.

Most authors refer to the sweetpotato as a root tuber rather than a true stem tuber. According to Winton (71, p. 105)* the chief structural characteristics of sweetpotatoes are as follows: "Tuberous roots, spindle-shaped, white, yellow, red, or purple with white to orange flesh. Cork cells in strippings quadrilateral in transverse rows. Cortex, phloem, and xylem with starch cells, crystal cells, and latex cells; starch grains of tapioca-type, up to 50μ; vessels pitted, up to 80μ, often surrounded by meristematic cells forming a cobweb tissue."

Sweetpotatoes are grown mostly for human consumption. Under the present program of production, the price which they bring for table use largely precludes their consideration as livestock feed. However, chemical analyses of sweetpotatoes, as well as the results of numerous feeding tests, indicate that they are valuable as feed for practically all classes of farm animals when used in properly balanced rations. Therefore, under a more extensive program of production, resulting in lower costs, sweetpotatoes might easily become one of the most important feed crops of the Southern States.

It has been shown that when sweetpotatoes are properly dried they may be ground into meal or flour which can be preserved indefinitely under good storage conditions. Recent developments in the dehydration of sweetpotatoes have increased the possibilities of this crop for human and stock consumption. Roughly, 300 pounds of sweetpotatoes when dehydrated will make 100 pounds of meal.

The starch plant of Sweetpotato Growers Inc. (a cooperative organization) at Laurel, Mississippi, has demonstrated that high grade starch can be made from sweetpotatoes. While being suitable for ordinary uses, this starch can also be used in the manufacture of adhesives. Tests have proven that the starch is equal, if not superior, in quality to other starches when used for sizing cotton yarns, fabrics, and paper. Sweetpotato starch yields a gel of high water content and tender consistency, which property makes it desirable for use in custards and puddings. In 1937 only 500,000 pounds of sweetpotato starch were produced in this country as compared with the 9 million pounds of white potato starch and 900 million pounds of cornstarch. Roughly, 3 tons of sweetpotato starch can be produced per acre in some parts of the United States under proper conditions. If alcohol from agricultural products is ever used as a motor fuel in this country, the sweetpotato would be an eminently suitable

* Literature citations on pages 74 - 79.

raw material. The development of the sweetpotato starch industry has been retarded because of the competition from imported cassava flour which sells at a low price. The present war emergency may, temporarily at least, increase the interest in and production of sweetpotato starch (33, 56).

General Composition of the Sweetpotato: In Table 21 is shown the range of percentages for each principal constituent or group of constituents in sweetpotatoes, as found in the literature, and also the approximate average value of each constituent in a typical sweetpotato.

Table 21. General Composition of the Sweetpotato
(Fresh basis)

Constituent	Approximate Average for Typical Sweetpotato	Range
	Percent	Percent
Moisture	65.0	58 - 82
Starch	20.0	10 - 30
Cellulose	0.7	(0.7 - 5)[a]
Ligneous Material	1.0	0.9 - 1.2
Hemicelluloses	5.0	3 - 6
Total Sugars	3.0	3 - 20
Protein (N x 6.25)	2.0	1 - 4
Fat	0.5	0.5 - 2.5
Ash	1.0	0.7 - 8.0
Other	1.8	-

[a] Calculated as crude fiber.

Mineral Constituents: The principal mineral constituents of the sweetpotato, as determined on the ash, are shown in Table 22. The elements found in the ash (71), as well as the proportions or amounts in which they are present, are typical of plant ashes. The potassium content is very high. Sodium, calcium, magnesium and phosphorus are present in relatively high quantities, and the other elements commonly found in plant ash occur in lesser amounts.

Table 22. Mineral Constituents of the Sweetpotato as Percent of Ash

Constituent	Percent
K_2O	58.2
Na_2O	8.1
CaO	5.6
MgO	4.1
Fe_2O_3	0.5
Mn_2O_3	trace
P_2O_5	16.2
SO_3	3.0
SiO_2	2.1
Cl	2.6

The minor mineral constituents that have been reported in the sweetpotato are iron, manganese, copper, and zinc. Iron is present in amounts of 5-9 mg. per kg. on a fresh sample basis (57, 62) and from 39 - 88 mg. per kg. on a dry sample basis (59). Manganese has been reported in quantities which range from 2.6 to 17.7 mg. per kg. on a dry basis (59). The copper content of the sweetpotato is 1.5 mg. per kg. on a fresh basis (39) and varies from 3.4 to 8.8 mg. per kg. on the dry material (59, 60). The zinc value is 2.3 mg. per kg. on a fresh basis (6).

The term "minor" applies to quantity only, as these elements are quite significant from a nutritional viewpoint. Evidence of the value of traces of copper and manganese as adjuncts to iron in hemoglobin building makes information desirable regarding the quantities of these elements present.

Small amounts of iodine, up to 87 parts per billion, have been found in the sweetpotato (22).

Porges and Sherman (58) have determined the effects of extracting sweetpotato flesh with cold water, alcohol, ether, hydrochloric acid, and sulfuric acid, and (with their permission) the results are shown in Table 23.

Table 23. Proximate Composition of Selected Varieties of Sweetpotatoes (Calculated as Percent of Fresh Material)

	Triumph	L-5	Porto Rico	Wenholz	B-52
	Percent	Percent	Percent	Percent	Percent
Moisture	61.11	59.62	61.30	59.91	57.01
Water-Soluble Portion	7.67	5.78	8.55	6.37	6.96
Alcohol-Soluble Portion	0.56	0.49	0.48	0.42	0.76
Ether-Soluble Portion	0.02	0.02	0.01	0.01	0.05
HCl-Extractable	29.27	32.61	28.08	32.09	33.61
H_2SO_4-Extractable	0.40	0.51	0.43	0.36	0.46
Lignin Portion	0.90	0.93	1.08	0.81	1.10
Residual Protein	0.04	0.04	0.03	0.02	0.04
Total accounted for	99.97	100.00	99.96	99.99	99.99
Starch	24.37	29.92	23.68	29.33	26.38
Protein (N x 6.25)	2.22	2.59	2.41	1.71	1.72

Cold-water extraction removes such water-soluble materials as sugars, amino acids, certain proteins soluble in water, organic acids, alcohols, salts, some pigments, and some enzymes. Alcohol extraction removes waxes, resins, bitter substances, alkaloids, chlorophyll, additional pigments, tannins, terpenes, choline, and higher alcohols. Ether extraction removes fatty and ethereal oils, part of the waxy resinlike substances, and certain nitrogenous fats. Extraction with 2 percent hydrochloric acid converts the hemicellulosic fraction of those carbohydrates not soluble in water but soluble in boiling dilute acid to a solubilized form. These include both pentosans, (araban, xylan, etc.), and hexosans, (galactan, mannan, etc.), as well as starches, pectins, and some proteins. Extraction with 80-percent sulfuric acid changes

the true celluloses or carbohydrates not soluble by previous treatments to solubilized sugars. Protein and other substances may also be found in this extract. The material remaining after these treatments is considered as consisting of the ligneous fraction and residual nitrogenous material calculated as protein. Determinations of moisture, starch, and protein were made on the freshly ground material at the time the water extraction was under way.

Starch: Jones (27), in the 1930 Yearbook of the Department of Agriculture, states that the average starch content of sweetpotatoes is about 18%. Shiver (63) reports starch values from 10 percent to 30 percent. Labayen (36) reports that the camote or the sweetpotato of the Philippines contains from 10 to 26 percent of starch. Miller (47) has developed varieties which run as high as 28 - 30 percent starch, or about 5 percent higher than in the Triumph variety, the best starch-producing commercial variety in this country. Forges and Sherman (58) have shown high starch values for four varieties which run from 26 to 30 percent. Culpepper and Magoon (9) have analyzed a large number of sweetpotato varieties and find a starch range of from 18 to 30 percent. For the average sweetpotato, 20 percent starch seems to be a fairly good average.

Very little work has been done on the fractionation of starch from sweetpotatoes. That there are two components in starch is a well established fact. One fraction, the soluble portion called amylose, consists of long, unbranched chains of glucose units bound by alpha 1 : 4 glucosidic linkages and gives an intense blue color with iodine. This amylose fraction retrogrades easily. Beta-amylase hydrolyzes this fraction completely. The other fraction, the insoluble portion called amylopectin, consists of highly-branched chains with alpha 1 : 6 glucosidic linkages and gives a purple to red color with iodine. Beta-amylase hydrolyzes approximately 60 percent of the amylopectin.

There are a number of methods for separating the two components of starch. Among them are Schoch's (61) method, in which the amylose fraction is selectively precipitated with 1-butanol. Bates, French and Rundle (5) use an iodimetric potentiometric titration method in which a starch suspension is titrated with iodine. The activity of iodine added to an amylose solution remains essentially constant until the complex formation is complete; in contrast, there is a continual rise in the activity of iodine added to an amylopectin solution. If the milliliters of iodine added to a solution containing both are plotted against potential measurements on the reaction mixture a sharp break in the curve is obtained, and the point of inflection gives a measure of the amylose. Meyer (46) uses a hot-water extraction for the separation of the two components, but yields of only about 2 percent amylose are obtained. Pacsu and Mullen's (55) method of absorbing the amylose fraction on cotton is satisfactory for the isolation of amylopectin, but it is difficult to elute the amylose from the cotton.

An electrophoresis cell may also be used to separate the two fractions of sweetpotato starch. Such a cell was used by Thurber (67) who, so far as we know, gives the only available information on the ratio of the two fractions in sweetpotato starch. In the electrophoresis-cell method, the amylopectin or insoluble portion has a negative charge and migrates to the positive pole where it can be collected.

Sweetpotato starch gelatinizes at 67° C. (67).

Balch (4) believes that the specific rotation of sweetpotato starch is about 193°.

Sugars: Crystalline sucrose was isolated from fresh sweetpotatoes by Stone (64). Miyake (49) showed that the reducing sugars in the sweetpotato are dextrose and levulose, and that the nonreducing sugar is sucrose; also, that maltose, pentose, galactose, and mannose are absent. He extracted 100 grams of sweetpotato in a Soxhlet extractor with ether, then with 95% alcohol. It was necessary to extract for two weeks in order to remove the last traces of sugar. The sirup was evaporated down to about 10 cc. and subjected to qualitative tests.

From these tests Miyake concluded that the sweetpotato has both reducing and nonreducing sugars; the presence of glucose and fructose is probable, and since he obtained no test for pentose or mannose he concluded these were absent. Miyake isolated crystals from the sirup; after purification by crystallizing from alcohol, these showed the same specific rotation as did sucrose. From the sirup he formed a phenylglucosazone, thus demonstrating the presence of glucose. No osazone corresponding to that formed by maltose was found.

Maltose, although not present in the fresh sweetpotato, forms in large quantities during baking and cooking, probably due to the diastase present in the sweetpotato (18, 64).

The total-sugar value varies considerably throughout the literature, but it is believed that sweetpotatoes, when freshly harvested, will analyze approximately 3.0 percent total sugars (9, 24, 32, 36, 58, 63, 70, 71).

Pectin: Yanovsky (73) states that the presence of pectin in the sweetpotato has been long known to various investigators, although a survey of the literature has not disclosed this. He states that the extraction of the approximately 2 percent pectin from the sweetpotato, containing about 20 percent starch and other constituents which interfere with pectin, would hardly prove to be a practical commerical proposition. Porges and Sherman of the Sweetpotato Products Division of the Southern Regional Research Laboratory have observed that pectin is present in amounts from 2 to 3 percent (58).

As a result of a recently developed sweetpotato starch industry a byproduct, sweetpotato pulp, is now available in large quantities. During the starch manufacture, the pectin is concentrated in the pulp to the extent of about 15 percent (73). Porges and Sherman have found that pulp sometimes runs as high as 20 to 30 percent pectin (58). It is therefore a potential commercial source of pectin.

In preliminary work, pectin has been extracted from pulp with dilute acids, alkalies and ammonium oxalate. The product obtained makes a firm jelly with sugar solutions. Work is now in progress to find suitable commercial methods of extracting the pectin from the sweetpotato. Elwell and Dehn (11) describe the pectin molecule as being a long chain of polygalacturonic acid units combined through intramolecular forces and anhydride structure to form insoluble protopectin layers of the cell wall and middle lamella. According to them, single treatment with water or acid does not remove any definite pectic compound but a series of pectic substances, and continued hydrolysis

progressively dissolves the entire protopectin layer. They removed pectin from the sweetpotato as follows:

Table 24. Extraction of Pectin from Sweetpotato

Extract	Wet Basis	Dry Basis
	Percent	Percent
Water-soluble material	1.63	4.80
Easily hydrolyzable protopection	0.99	2.91
Difficultlyhydrolyzable protopectin	0.95	2.79
	3.57	10.50

The first extraction involved only boiling with water (one hour) and squeezing the extracted material. The second was a sulfuric acid plus water boiling for one hour (acid strength was 0.155 ml. of H_2SO_4 to 500 ml. H_2O, pH 1.5). The third was acid-water boiling as in the second extraction but for two hours. The pectin was determined by precipitation with alcohol. Results are shown in Table 24.

Heinze and Appleman (21) have recently shown that, for Maryland Golden Sweetpotatoes, soluble pectin increases during curing and decreases in storage, while the protopectin decreases during curing and increases in storage. They explain some of the increase in protopectin as being due to an actual increase in the total pectic substances. Furthermore, their studies indicate that the synthesis of protopectin during storage continues in the roots as long as they remain alive and sound. Total pectic substances as found in this variety of sweetpotato, on the fresh basis at harvest time, averaged about 0.8 percent. Pectic substances after approximately four and one-half months' storage totaled about 1 percent, calculated to the original weight.

Cellulose: Kohmoto and Sakaguchi (35) found 2.69 percent cellulose in the sweetpotato on an air-dry basis by a special or improved method for the determination of cellulose. Their method appears to be quite similar to the Cross and Bevan method for determining cellulose.

Crude-fiber values range from 0.5 percent to 5.0 percent on a fresh basis (32, 58, 63, 70, 71).

Lignin: A search of the literature does not reveal any direct statement as to the quantity of lignin that might be present in the sweetpotato. Porges and Sherman (58), however, do estimate a lignin-like material in their study of the constituents of the sweetpotato, and report about 1 percent on the fresh basis.

Hemicellulose: Yanovsky (72) found 18.7 percent pentosans in the pulp (dry basis) in his study of the extraction of the hemicelluloses from sweetpotato pulp.

Porges' and Sherman's (58) value runs about 4 - 5 percent on a fresh basis for hemicelluloses on the whole potato.

Shiver (63) in a number of analyses of sweetpotatoes of different varieties found that the nitrogen-free extract averaged about 31.7 percent. This value includes about 23 percent starch, 2.4 percent sucrose and 0.6 percent glucose. This leaves 5 or 6 percent unaccounted for which, he believes, is mostly pentosans. If one considers that pectin is present in amounts of 2 - 3 percent, pentosans might then be present to the extent of 2 - 3 percent.

Carbohydrate Transformation: Hasselbring and Hawkins (19) found that in stored sweetpotatoes the starch is first converted into the reducing sugars and that sucrose is then synthesized from the reducing sugars. The rates of starch hydrolysis and the synthesis of cane sugar in a general way conformed to van't Hoff's temperature rule for rates of chemical reaction. At high temperatures the reactions were rapid at first but soon became slower and approached an end point. At low temperatures the rates were slower and the end point was so shifted so as to permit a greater concentration of the sugar. The reactions were continuous. In the growing sweetpotato, the concentration of the sugars remained comparatively low. The extensive conversion of the starch into sugars appeared to be inhibited by the activity of the vines. When the vines were destroyed and the flow of materials to the roots was interrupted, the carbohydrate transformations characteristic of stored sweetpotatoes began, even if the roots were left in the ground. These authors showed also that the sugar in sweetpotatoes increases at 6 - 7° C. to a greater extent than at 12 - 30° C.

Hopkins and Phillips (24) found that the sweetpotato when freshly harvested contained about 2.5 percent sucrose, which during curing at 85° F. changed to about 3.3 percent. When thus cured and placed at constant temperature such as 50° - 55° F., the sucrose content increased but it decreased at 60°, 65°, and 70° F. When uncured sweetpotatoes were placed at these temperatures the sucrose content increased at 50° and 55°, while at 60°, 65°, and 70° there was first an increase and then a decrease.

Protein: The protein content of the sweetpotato varies from about 2 to 4 percent on the fresh basis (27, 52, 70, 71). According to Jones (27) the proteins yield valuable amino acids. The sweetpotato is richer in protein than the white potato. About half of the nitrogen of the white potato is present in amide groups and have no food value.

Jones and Gersdorff (28) found ipomein, a globulin, in a 5-percent sodium chloride extraction of sweetpotato pulp. A secondary protein with albumin-like properties is formed from ipomein by enzymic decomposition or when sweetpotatoes are improperly stored.

The most significant difference between the ipomein of sweetpotatoes and the tuberin of white potatoes is that the former contains approximately twice as much sulfur. Table 25 gives the analyses of Jones and Gersdorff on the ipomein and secondary protein of the sweetpotato, and in addition, the amino acids found by Kao, Adolph and Liu (31) in their studies of sweetpotato protein.

Table 25. Elementary and Amino Acid Analysis of Protein Found in Sweetpotato (Expressed in terms of ash-free and moisture-free proteins)

	Jones and Gersdorff (28)		Kao, Adolph, and Liu (31)
	Ipomein	Secondary protein	Sweetpotato protein
	Percent	Percent	Percent
Amide N[a]	8.87	8.44	-
Cystine	1.42[b]	1.62[b]	2.5[c]
Arginine	6.13	4.79	5.9
Histidine	3.19	2.5	1.3
Lysine	4.9	4.98	4.5
Tryptophane	2.69	4.78	2.1
Tyrosine	7.03	6.57	5.0
C	51.79	53.5	-
H	7.19	6.53	-
N	16.16	15.26	-
S	2.25	1.73	-

a/ The values given for amide nitrogen are expressed in percentages of total nitrogen.

b/ Jones and Gersdorff also obtained cystine values of 2.65 percent for the Ipomein and 2.49 for the secondary protein by the Van Slyke Method.

c/ These values have been recalculated from the data of Kao et al. for comparison with those of Jones and Gersdorff.

Kao, Adolph, and Liu isolated the protein from the sweetpotato by pressing the juice from the fresh tubers, allowing it to stand 3 - 4 hours for starch to settle, and then filtering. The juice was then acidified with acetic acid sufficiently to change the color of Congo red and the protein was precipitated by passing steam into the turbid solution while heating on the water bath. The coagulated protein was filtered, washed with alcohol and ether, and dried at 60° C. in the vacuum oven. The yield from 350 kg. of sweetpotatoes was 400 g. of crude protein. The color of the protein was a light gray.

Probably the most complete picture of the nitrogenous compounds of the sweetpotato is presented in Table 26 which represents the data of Nightingale, et al. (52) obtained in their work on the preservation of plant tissues by freezing.

Table 26. Nitrogen Contents of Sweetpotatoes Broken Down into Types of Nitrogen Compounds Present (Expressed in percent of dry matter)

Constituent	Sample 1	Sample 2	Sample 3
	Percent	Percent	Percent
Dry matter	19.800[a]	25.540[a]	19.440[a]
Total nitrogen	1.462	0.439	1.420
Unextracted nitrogen	0.130	0.084	0.302
Coagulable nitrogen	0.358	0.111	0.617
Protein nitrogen	0.488	0.195	0.919
Soluble nitrogen	0.974	0.244	0.501
NO3-free, soluble nitrogen	0.972	0.244	--
Proteose nitrogen	0.544	--	0.092
Basic nitrogen	--	0.165	--
Amide nitrogen	0.096	0.013	0.092
Amino nitrogen	0.150	0.062	0.126
Ammonia nitrogen	0.053	trace	0.065
Humin nitrogen	--	trace	--
Nitrate nitrogen	0.002	none	0.047
Other nitrogen	0.129	0.004	0.132

a/ On weight of sample as received.

Heinze and Appleman (21) studied the nitrogen metabolism in Maryland Golden Sweetpotatoes during curing under different combinations of atmospheric temperature and humidity and also during subsequent storage. At the time of harvest the total organic nitrogen of the roots averaged only 0.2 percent of the fresh weight or 0.8 percent of the total solids. The nonprotein nitrogen in the sweetpotatoes at harvest time ranged from 22 to 33 percent of the total nitrogen. Under all the curing conditions the nonprotein nitrogen increased, while the protein nitrogen decreased, indicating protein hydrolysis. The rate of hydrolysis was somewhat higher at the higher curing temperatures. Fairly consistent increases in basic, amide, and residual nitrogen occurred in all lots, but a consistent increase in amino nitrogen occurred only in those lots cured at the high temperatures of 95° and 104° F.

The nitrogen distribution in sweetpotatoes stored at 50 - 53° F. remained fairly stable during most of the storage period. However, there was a slight increase in amide, basic, and residual nitrogen near the end of the storage period.

There was no apparent difference in the nitrogen distribution of the proximal and distal halves of the Maryland Golden Sweetpotato.

It might be interesting to note that in the experiments of Adolph and Liu (1) it was found that 3 adults who were fed sweetpotatoes only for a period of 5 to 8 weeks maintained a nitrogen balance with a daily intake of 2 kilograms of sweetpotatoes.

Kao, Adolph and Liu (31) report a biological value of 74 for the protein of sweetpotato, a figure which gives it a high rank among the vegetable proteins. Experiments with rats in their laboratory have demonstrated that a diet consisting exclusively of cooked sweetpotato is quite satisfactory for maintenance but does not provide adequately for growth.

Phosphorus Compounds: Ose (53) extracted from commercial dried sweetpotatoes with 96-percent alcohol at 50-60° C., two monoaminophosphatides which may have been of the lecithin or cephalin type.

Engle (12) in examining animal and plant products for choline content found 0.36 mg. of choline as the chloride per gram of sweetpotato on a dry basis. Choline is ethanol-trimethylammonium hydroxide ($HOCH_2CH_2NMe_3OH$) and is an important nutritional factor.

Bagaoisan (3) estimated the phytin content of the sweetpotato to be 1.05 percent on a dry basis. He used the method of Averill and King (2) for its quantitative determination. Phytin is generally considered to be the calcium-magnesium salt of inositol hexaphosphate. Phosphorus in the phytin form is of questionable value from a nutritional viewpoint and as a consequence has been the subject of considerable controversy.

Phytosterol and Phytosterolin: Matlack (44) separated a phytosterol and a phytosterol glucoside during the isolation of carotene from the sweetpotato. The glucoside, phytosterolin, was separated from a concentrated solution of the sweetpotato pigment before saponification, and the phytosterol was removed from a concentrated extract of the material remaining unsaponified by alcoholic potassium hydroxide. After repeated recrystallization of the crude phytosterolin from dilute pyridine, the melting point was found to be 285-286°; the acetate derivative melted at 165-165.5°. With careful manipulation, a positive Salkowski sterol reaction and an alpha napthol test were observed on the parent substance.

After two recrystallizations of the phytosterol from ethyl alcohol-ethyl acetate mixture, it melted at 136.5-137° and gave both the Lieberman-Burchard and Salkowski reactions for sterol. On treatment with acetic anhydride an acetate was formed which melted at 129-129.5°.

From these observations, Matlack concluded that the phytosterol consists chiefly of sitosterol and that the phytosterolin consists chiefly of sitosterolin glucoside.

Organic Acids: Only two organic acids have been reported to be present in the sweetpotato. Henry (23) in 1825 reported free malic acid and calcium malate, along with some mineral constituents, in the amount of 1.4 percent. His identification of the malic acid was not positive for he said he believed the compound to be malic acid because of the formation of a precipitate with lead acetate. No other reference has been found in the literature in regard to presence of malic acid in the sweetpotato. Viehover, Kunke and Mastin (68) reported 0.10 percent oxalic acid. It is believed that other organic acids are present, but their identities have not been determined to date.

Porges and Sherman (58) analyzed the water-soluble portions of sweetpotatoes shown in Table 23 for sugars, protein, and ash and found about 2 percent of other water-soluble organic matter which was believed to be in part organic acids.

Carotene and Vitamin A: Lease (37) has stated that the yellow pigment of the sweetpotato (Porto Rico) is almost entirely carotene. Matlack (45) extracted the pigments from the Porto Rico sweetpotato alternately with acetone and petroleum ether and concluded that the predominant pigment in the sweetpotato is beta carotene with a small amount of xanthophylls, one of which is violaxanthin. He based these conclusions on the melting point of the purified crystalline carotene (182° C.) and on spectral absorption maxima. The absorption maxima of sweetpotato carotene, in comparison with those of beta carotene, and absorption maxima of the xanthophyll fraction of sweetpotato, in comparison with those of leaf xanthophyll, are shown in Table 27.

Table 27. Positions of Centers of Absorption Bands in Angstrom Units

(Beta) Carotene		Sweetpotato Carotene		Leaf Xanthophyll		Xanthophyll Fraction From Sweetpotato	
Room Temperature	Liquid Air Temperature	Room Temp.	Liquid Air Temperature	Room Temp.	Liquid Air Temperature	Room Temp.	Liquid Air Temperature
4815	5000	4825	5010	4760	4900	4755	4895
4490	4670	4500	4680	4430	4580	4440	4590
4230	4375	4230	4375	4190	4300	4190	4310

Matlack was unable to isolate the xanthophyll from the alcohol phase because of its small amount and the large amount of impurities. However, he did obtain one fraction which gave a blue color with formic acid and concentrated hydrochloric acid; this reaction indicated the presence of violaxanthin.

Villere et al. (69) recently investigated the carotene of sweetpotatoes and concurred with Matlack that it is principally the beta isomer.

Lease and Mitchell (38) working with Porto Rico sweetpotatoes, reported an average of 40 micrograms of carotene per gram of fresh sample and 130 micrograms of carotene per gram of sample on a dry-weight basis. Miller and Covington (48) have developed varieties of sweetpotatoes that contain as much as 151.5 micrograms of carotene per gram of fresh sample, or twice as much as any present table-stock variety. They found that the carotene content of the Porto Rico variety increased 50 percent in the first month of storage. There was a gradual increase in the second month of storage and then the value became constant. At the time of harvest the carotene value in terms of micrograms per gram was 51.0. After three months' storage the value had increased to 80.2 micrograms.

The vitamin A contents of five varieties of sweetpotatoes have been studied by MacLeod, et al. (41). The Porto Rico and Yellow Jersey types were studied - first, directly after harvesting and, again, two or more months after harvesting. The Nancy Hall, Triumph, and Southern Queen were tested only after they had been stored for some time. The Nancy Hall variety was found to contain 30 Sherman-Munsell Units of vitamin A per gram; the Triumph, 2 units per gram; and the Southern Queen, 4 units per gram. The Porto Rico, directly after harvesting, contained 20 units per gram, and after 2 or more months' storage it contained 65 units per gram, which is more than three times the original vitamin A content. The Yellow Jersey showed about four times its original vitamin A content after storage for 2 or more months. The value obtained for this variety at time of harvest was 10 units, and after storage 40 units, per gram. Swanson et al. (65) found the average concentration of vitamin A in the Prolific variety to be 23 International Units or 56 Sherman-Munsell Units per gram. Other values in the literature vary from 0.75 International Units of vitamin A per gram to 70 Sherman-Munsell Units per gram (10, 13).

The human requirement of vitamin A is roughly 4,000 I. U. per day, which is equivalent to 2,400 micrograms of beta carotene or 50 grams of raw sweetpotatoes. A person eating 150 grams of sweetpotatoes two or three times a week will have all the vitamin A needed even though he obtains none from any other source (37). Carefully dehydrated sweetpotato contains 90 percent of the carotene originally present in the raw vegetable.

Vitamins of B Complex: Blackberg (7) found an abundance of vitamin A and a small amount of vitamin B (complex) in canned sweetpotatoes. De Caro and Locatelli (10) estimated the quantity of B_1 in the variety they analyzed as 0.5 I.U. per gram; B_2 (riboflavin) was present in the amount of 2.5 biological units. Munsell (50) found about 50 micrograms of riboflavin per 100 grams of sample (variety not indicated). MacLeod et al. (42) found approximately 0.7 unit of vitamin B (complex) per gram in the Nancy Hall potato. MacLeod (40) reported 0.5 vitamin G (B_2, riboflavin) unit per gram of sweetpotatoes.

Nicotinic acid is present in the sweetpotato according to Tepley, et al. (66). On a dry basis they found 4.53 mg. per 100 grams.

Jukes (29) regards the sweetpotato as an excellent source of pantothenic acid because it contains more than 28 micrograms per gram of sample (dry).

Vitamin C (Ascorbic Acid): Vitamin C has been reported in amounts of from 0.7 to 0.9 mg. in 10 grams of fresh sweetpotato and 0.6 mg. in 10 grams of the cooked vegetable (10). Newton and Lowry (51) showed that the Porto Rico sweetpotato contains slightly less than 0.2 Sherman Units per gram when raw or boiled and two thirds of that quantity when baked.

Vitamins Summary: A summary of the vitamin contents of sweetpotatoes as found in Practical Physiological Chemistry by Hawk and Bergeim (20), is as follows: Vitamin A, 1,000 to 7,000 I.U. per 100 g.; vitamin B (B_1), 15 to 35 I.U. per 100 g.; vitamin C, 100 to 300 I.U. per 100 g.; vitamin G (B_2), 30 to 40 Sherman-Bourquin Units per 100 g.

Enzymes: Johnstone (26) in a study of the physiology of two varieties of Ipomea batatas, Porto Rico and Triumph, has concluded that peroxidase, catalase, laccase, and amylase are present, and tyrosinase is absent, in both varieties. The presence of peroxidase was demonstrated by treating the tissue with guaiacum and hydrogen peroxide. Oxidation of the guaiacum to guaiacum blue under these conditions was more rapid in every case, indicating the presence of peroxidase. The presence of laccase was proven by treating the varieties with tetramethyl-phenylendiamine hydrochloride and subjecting them to tests with guaiacum. Laccase is distinguishable from peroxidase because it is stable at 60-70° C. while peroxidase is unstable at 60-65° C. Catalase activity was determined by measuring the volume of oxygen liberated by the samples giving optimum activity with 5 ml. of standardized neutral hydrogen peroxide. Amylase activity was demonstrated and measured by determining the volume of aqueous extract required to hydrolyze 5 ml. of a 1-percent solution of soluble starch. No test for tyrosinase was observed when the alcoholic precipi/tate from an aqueous extract was redissolved and tested with a suspension of tyrosin. No apparent coloration occurred even after twelve hours.

Johnstone also observed that the Porto Rico variety has greater enzymatic activity, greater respiratory activity, and a higher moisture content than any other varieties.

Giri (16) states that sweetpotato amylase acts like pure β-amylase from barley. The amylase selectively hydrolyzes a portion of the starch substance leaving a residual material which resembles erythrogranulose. This is hydrolyzed by α-amylase from barley. Amyloamylose is hydrolzed by both enzymes without inhibition and the color of iodine remains unchanged until almost complete saccharification takes place. Giri (15) purifies the amylase by adsorption with alumina gel. The adsorption of the enzyme is independent of its initial concentration and is at a maximum between pH 3.7 and 4.2. He concludes, contrary to modern concepts of enzyme chemistry, that the enzyme is not a protein and does not contain any noticeable amount of protein.

Giri (14) states that the active enzyme can be prepared by extracting dried sweetpotato with water and precipitating with alcohol. It can be further purified by dialysis, which increases its activity seven-fold. The optimum hydrogen ion concentration for the enzyme is pH 5.5-6.0 and optimum temperature 50-55° C. The process of heat inactivation follows a unimolecular course. It is most stable in a pH range which corresponds to its maximum activity. The amylolytic activity increases in passing from the skin to the center of the tuber, the innermost portion having three times the activity of the layers near the surface. The enzyme is mostly saccharogenic resembling cereal amylases and differing from white potato amylase and similar enzymes of animal organisms.

Gore (17) has shown that the diastatic enzymes of the tuber dissolve nearly all the starch in one and one-half hours at temperatures from 60 to 100°. Tests on diastatic power of extracts of sweetpotato and sweetpotato flour showed values according to Lintner's method as follows:

	Degrees Lintner
Porto Rico Fresh Pulp	300
Nancy Hall Fresh Pulp	125
Porto Rico Flour	500
Nancy Hall Flour	300
Big Stem Jersey Flour	160

Recently Bois and Savary (8) have published data on the saccharases and sugars of both the sweetpotato and the white potato. They found two amylases in the sweetpotato, one a maltose-producing enzyme, the other a sucrose-producing enzyme. They have stated that invertase is also present. They could find no evidence that maltase exists in the sweetpotato. Their evidence for the presence of an enzyme in the sweetpotato that converts starch to sucrose is not convincing.

Resinous Substances: At the present time the only available information regarding the resinous substances of the sweetpotato is that furnished by Ose (54). This author has done an extensive piece of work pertaining to the extraction, identification, quantitative estimation, and uses of the latex found in the sweetpotatoes. He found that the resinous substance of the milky liquid was easily soluble in ether and alcohol, identified it as jalapin, which contains a glucoresin, and attributed the resinous property of the milky liquid mainly to the jalapin in it. The quantity of jalapin in tubers varies according to different stages of growth. The largest amount found was 0.70 percent and the lowest 0.28 percent on a moisture-free basis.

Ose says "The amount of jalapin is greatest in the hypodermic part of the tuber, less in the central part and least in the middle part." Of interest is Ose's interpretation of why sweetpotatoes are utilized as a "boiler compound" for steam boilers in Japan. Supposedly jalapic acid is formed from jalapin of the tubers in the boiler, which exerts, to a certain degree, a preventive action against the precipitation of calcium and magnesium carbonates from their bicarbonate solutions, and calcium sulfate from its solution. From experiments, Ose concludes that there must be some connection between the chemical and colloidal properties of jalapic acid, and the reason why sweetpotatoes are used as a kind of "boiler compound". The presence of jalapin in the tubers is therefore quite important and, in addition to the above use, Ose has attributed another function, that of purgation, to the jalapin in sweetpotatoes and sweetpotato products. This observation may be of interest from a physiological viewpoint.

Tannins: Although quantitative determination is lacking, qualitative tests indicate that tannin-like materials exist in the sweetpotato. Kohman (34) in studying the discoloration in canned sweetpotatoes found that tannin-like materials present in the potato unite with the iron from the can to produce a dark color. The substances involved are largely localized just under the skin.

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Subject	Commodity and page			
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Cephalin		27	46,49	69
Ceryl alcohol	6			
Chlorine	9	20,23	45,	61
Chlorogenic acid	9	30		
Chlorophyll		23		
Choline		28	46	69
Chroman-5, 6-quinones		22		
Cobalt			45	
Colloidal "sugars"		26		
Composition, general	3,4,10	19,20	40,41,43, 47,48	61
Conarachin			42,43,44,45	
Copper	9	20	45	62
Cotton fiber	3			
Cottonseed		19,26		
Crude fiber		20	41,43,50,51	65
Cystine		24,25,26	44	67
Daturic acid			49	
Development	3,9		39	
Dextrins		26		
Dicarboxylic acid nitrogen		25,26		
Digestibility, coefficient of			45	
Dipalmitin		23		
Elaidinisation			49	
Enzymes	3	3,29	3,47	3,72
Ergosterol		22,30		
Ether extract	12	20	41,42,51	61
Expeller presses			39	
Extractives				62
Factor, converting nitrogen to protein		23	45	
Fat			50	61
Fatty acids	6,7	21,27	47,48,49	
Fineness	11			
Flavones	9			
Flowers			39	
Fluorine		20	45	
Food value			39,52	60
Free fatty acids		21	42	
Fructose	9			64
Furfural		27		
Galactans			46	
Galacto-araban			46	
Galactose		27	46	64
Germ			39	
Globulins		23,24,25	43	

Subject	Commodity and Page			
	Cotton fiber	Cottonseed	Peanut	Sweetpotato
Glucides			43	
Glucose	9	27		64,66
Glucose, d- in sterol glucosides		22		
Glucosides	3	3	3	3
Glutamic acid		24,26	44	
Glutelin		23		
Gluten			43	
Glycerides		21	47,48,49	
Glycerol	6			
Glycine		24	44	
Glycuronic acid, d-		27		
Gossypol	3	3,28,29,30	3	3
Gossypurpurin		29,30		
Green lint cotton	6			
Hay			39	
Hemicellulose		26,27		61,62,65
Heneicosanoic acid			49	
Heptacosane	6			
Hexacosanoic acid			48	
Hexadecenoic acid		21,27		
Hexoses	3,9	3, 27	3,46	3,64,66
Histamine	8			
Histidine		24,25,26	44	67
Hulls		19,20,21,27	39,50,52	
Humin nitrogen		24,26	44	68
Hydraulic presses			39	
Hydrocarbons	6	23	49	
Hydroxylysine		25	44	
Hysteresis, moisture	5			
Immaturity	10			
Inositol hexaphosphoric acid		28		69
" pentaphosphoric acid		28		
" phosphoric acids		28		
" triphosphoric acid		28		
Iodine		20		62
Iodine number			42	
Ipomein				66
Iron	9,12	20,23	45	61,66
Isobehenic acid			49	
Isoelectric point		23	43	
Isoleucine		25	45	
Jalapin				73
Kernels		19,20	39,47	
Kier boil	7			
Laccase				72
Lactic acid		30		
Lauric acid			48	
Leaves			39	
Lecithin		27	46,49	69
Leucine	8	24,25	44	
Lignin	12	27		61,62,63,65

Subject	Commodity and Page: Cotton fiber	Cottonseed	Peanut	Sweetpotato
Lignoceric acid			48	
Linoleic acid		21,27	48	
Linters	7,12	19,21		
Lipase		29	47	
Lipids	3	3,20,21,27, 28	3,41,42,43 50,51	3
Lysine		24,25,26	44	67
Magnesium	9	20,23	45,51	61
Magnesium lactate		30		
Malic acid				69
Maltose				64
Manganese	9	20	45	61,62
Mannose				64
Marketing			39	
Meal		19,20	39,40,43,46	
Methionine		25	44	
Minor constituents	2	2	2	2
Moisture	5,12	20	41,50	61,62,63
Monoamino nitrogen		26		
Mucilagenous subst.		23		
Myristic acid		21	48	
Nickel		20		
Nicotinic acid			47	71
Nitrate	9			68
Nitrite	9			
Nitrogen content	3,9,11	3,23,24,25	3,42,43, 44,46	3,67,68
Nitrogen distribution		24	44	43,44
Nitrogen-free extract		20	41,43,50,51	66
Non-amino nitrogen		24	44	
Nonprotein nitrogen		24		
Nutritive value		28	39,44,45,46 52	60,62,66, 68,69
Odor of oil			49	
Oil		20,21	39,43,47, 48,49	
Oil color		29		
Oil mills			39	
Oil refining			47	
Oleic acid	6	21,27	48	
Oleodilinoleins		21		
Oleolinolein			49	
Oleomargarine			47	
Oxalic acid				69
Oxycellulose	9			
Palmitic acid	6	21,27	48	
Palmito-dilinoleins		21		
Palmitodiolein		21		
Palmito-oleolinoleins		21		
Pantothenic acid				71
Peanut			39	

Subject	Commodity and Page: Cotton fiber	Cottonseed	Peanut	Sweetpotato
Pectin	3,4,7,8,9, 10,11	3,26	3	3,64,65
Peduncle			39	
Pentosans	3	3,23,27	41,46,51,52	3,62,66
Pentoses	3,9	3,27	3	3,64
Pentose protein		23		
Peptones		23		
Peroxidase				72
Phenylalanine		24,25	44	
Phosphatides	3	3,27,28	3,46,49	3,69
Phosphoproteins		23,28		
Phosphoric acid, meta		28		
Phosphoric acid, pyro		28		
Phosphorus	9,11	20,23,28	45,46,49,51	61,69
Physetoleic acid			49	
Physical properties and composition	10			
Phytin		28	46	69
Phytosterol			49	69
Phytosterolin		23		69
Pigments	3,4,8,9	3,22,23,28, 29,30	3,52	3,62
Pigments - protein compounds		30		
Pods			39	
Polysaccharidic protein		25		
Potassium	9	20,23	45,51	61
Processing		19	39	
Proline		24	44	
Protein	3,4,8,9	3,20,23	3,41,42,43, 44,45,50,51	3,61,62,63, 66,67,68,70
Proteoses		22		
Purgative action				73
Quinic acid	9			
Raffinose		23,26		
Refining of oil		21,29	47	
Regain	5			
Resins	6	23		73
Respiration				72
Riboflavin (Vit. B_2 or G)		29	47	71
Ricin			46	
Runner peanuts			42	
Saponins	3	3,30	3	3
Scouring process	7,8			
Serine		24,25	44	
Settlings		22,23		
Shelling process			39	
Shells			39,50,52	
Silica	9	20,23	45,51	61
Sitosterol	6	22		
Sitosterolin	6			
Skin			39,49,50	